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Photographs of Comet Cunningham

By DANIEL M. POPPER

In the accompanying reproduction (Plate II) are shown six photographs of Comet Cunningham obtained with a six-inch camera of 32 inches focal length. The exposures were all made within the three weeks preceding perihelion passage of the comet. The width of the reproduction of each photograph corresponds to approximately 1.3 degrees.

The poor quality of the star images on the first photograph was caused by an attempt to guide on the head of the comet. The remaining photographs were guided on a star. There is considerable fogging from twilight in the last photograph.

On December 28 the general structure of the tail of the comet appears to differ from that of the other nights. Besides the flaring of the tail to the north-west (left) of its principal branch, which is pronounced on all of the photographs, a flaring is seen on that night to the south-east (right). On that date also the principal branch of the tail seems to leave the head at a point to the south-east of its center. By December 31 the tail has apparently regained its earlier form, though the diameter of the head appears smaller. The angle between the principal branch of the tail and its north-west flare remains approximately constant throughout the interval represented here.

McDonald Observatory,
Fort Davis, Texas, March 5, 1941.

Tides

By ARTHUR T. ADAMS

As the author of this paper intimates, the problem of the tides is alluring and perennial. The theory, relating to this problem, which is handed down through the textbooks does not entirely settle the question, even though the authority of some great names is associated with it. The adverse criticism to the point of view presented in this paper is that the reasoning is qualitative, and that the statements are not established by quantitative demonstrations. The lack of such demonstrations, however, is not in itself an indication of erroneous results. Quantitative work might prove or might disprove the conclusions. We deem the discussion to be of sufficient interest to justify its publication. EDITOR.

It has been stated that "every now and then a 'new theory' of tides is announced by someone who tells us that Newton and the other great minds who have labored in this field are all wrong as to the cause of the tide. . . . And it is a curious fact that these 'new theories,' which expound the 'true' cause of the tide, generally originate with people who live far inland, and not with mariners or others who are familiar with the various phenomena of the tides."

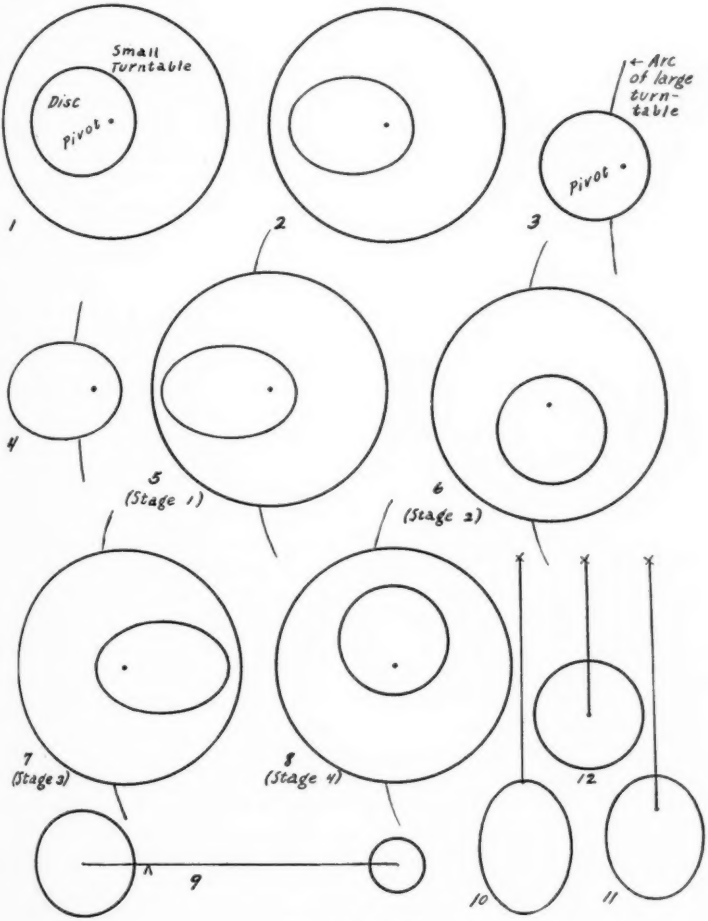
It is indeed hazardous for a layman to disregard such a friendly admonition, and especially so if he has passed all his lifetime near the geographical center of North America. In view of the fact, however, that doctors often disagree and that even great minds sometimes differ upon the profoundest of subjects, it may not seem so amazing if, now and then, a small mind differs with a great one.

With all due respect and admiration for such great minds as Isaac Newton, Lord Kelvin, George Darwin, and many others who have pondered this subject, the writer ventures humbly to submit a "new theory" upon the cause of ocean tides.

The universal explanation of ocean tides attributes the cause to the gravitational force of the moon (chiefly) and the sun upon the earth. All authorities agree that these bodies "pull" the water away from the solid central part of the earth because it is nearer (by Newton's law of gravitation) thus producing a rise of the water or tide directly under the moon and that the solid center is pulled away from the water on the opposite side, because nearer, thus causing a similar tide on the side opposite the moon.

To the writer it seems that these gravitational forces play no *direct* part in the cause of tides but that they are wholly due to the combined effect of centrifugal forces resulting from three distinct types of rotation involving the sun, earth, and moon—forces totally ignored by most

writers. Our primary problem, however, is not to determine the cause of tides, but to demonstrate the effect of these centrifugal forces upon the form of the earth. When this is done the tides will be virtually self-explanatory.



FIGURES 1 TO 12

We shall approach this subject by considering four hypothetical laboratory experiments with a flexible circular disc which will illustrate the principles involved better and more simply than with a flexible sphere. It will be necessary to check these experiments carefully, however irksome,

because they are the foundation of the theory herein advanced. These experiments may be actually performed if desirable but the results seem so obvious as to make this verification unnecessary.

Exp. 1. Place a circular disc of soft rubber, about ten inches in diameter and half an inch thick, upon a small turntable so that a pivot at the center of the turntable will pierce the disc at a point half way between the center and the circumference, as in Fig. 1. If the table is now rotated it is obvious that the disc will change from the circular to an elliptical form as in Fig. 2 (assuming the absence of friction and other obstructing elements). It is important to note and keep clearly in mind that *the effect of rotation is merely to change the disc from the circular to the elliptical form.* What was the *center* of the circle remains the *center* of the ellipse and the protuberances or bulges at the ends of the ellipse are *equal* during continuous and uniform rotation. This is the crux of this theory.

Exp. 2. Consider a large turntable and place the disc near the edge so that a post or pivot pierces the disc at the same point as in experiment 1, Fig. 3. By rotating this table the disc will change from the circular to the elliptical form as in Fig. 4. The bulges of the ellipse will be equal and the major axis will be constantly in line with the pivot and the center of the turntable.

Exp. 3. Place the small turntable upon the large one near the edge and place the disc upon the small table as in experiment 1. Now rotate both tables (the small one rapidly and the large one slowly), synchronizing their speeds so that the two centrifugal forces will be equal, resulting in two like ellipses if each were rotated separately. The effect of these two rotary motions upon the form of the disc during one complete rotation of the small turntable will now be considered in four stages.

Stage 1. When the small table has reached the position in its rotation where the center of the disc (ellipse), the center of the small table (pivot), and the center of the large table are in line, in this order, the two centrifugal forces will be acting in the same direction (outward), their combined forces producing an extra long ellipse, as in Fig. 5.

Stage 2. When the small table has advanced a quarter turn the two centrifugal forces will be acting at right angles to each other, each force tending to produce an ellipse. The result is a perfect circle, the forces being equal. In effect the circle may be considered as formed by two crossed ellipses, the bulges of one neutralizing the depressions of the other. Fig. 6.

Stage 3. When the small table has made a half turn the two forces will again be acting in unison as in the first stage but in *opposite* directions. At first thought the two forces would seem to cancel each other resulting in no bulge, but note the previous caution that the effect of rotation is to *change the disc from a circle to an ellipse,* the two bulges being *equal.* Since each force is effective their combined result is an extra long ellipse. Fig. 7.

Stage 4. At the end of a third quarter turn the conditions will be similar to the second stage, resulting in a circle, Fig. 8, and when the entire rotation is completed the disc will again become an extra long ellipse. Fig. 5.

It may be added that as the rotation of the small table proceeds (remember that the large table rotates slowly) the long ellipse (first stage) gradually shortens and widens until it becomes a circle at the end of the first quarter turn (second stage). Continuing, the circle gradually flattens and lengthens into the long ellipse at the end of the half turn (third stage). Thus in rotating, the disc alternates gradually from ellipse to circle and from circle to ellipse so long as both tables continue to rotate.

Exp. 4. We have thus far considered two rotary movements of the circular disc, namely: rotation around a pivot within the disc but to one side of the center, and a slow revolution around a distant pivot outside the disc. We shall now consider a third motion which is a rapid rotation of the disc upon *its own center*. To accomplish this we must regard the pivot in the center of the small turntable as nominal only, that is, although it is real and stationary, it must not interfere with the rotation of the disc around its center. Since the disc is flexible it will retain its varying elliptical form produced by the other two motions regardless of its rapid rotation on its own center. To illustrate, if a mark be placed on the perimeter of the disc the mark will move in and out from the center twice with every rotation, somewhat as the flat side of a deflated tire remains at the bottom of the wheel while it is rolling along on the ground.

At this point let it be observed that the varying bulges produced in this flexible disc are ***wholly*** due to ***centrifugal forces.***

The conclusions derived from these hypothetical experiments are, in principle, duplicated in the phenomena observed in the system of the sun, earth, and moon. In the experiments ideal conditions have been adopted for the sake of simplicity but, except for certain necessary modifications to be noted hereafter, the analogy is perfect.

Let us now apply these principles to the actual phenomena and endeavor thus to demonstrate the truth of this analogy. The following variations from the experimental data will first be noted, however. The earth is a sphere, not a disc. The two centrifugal forces are unequal. The material of the earth is a slightly pliable center covered with a uniform layer of water (assuming ideal conditions). The sun replaces the center of the large turntable. The pivot in the center of the small turntable represents the common center of gravity of the earth-moon binary system. This point is three-fourths of the radius or 3,000 miles from the center of the earth. The earth-moon *monthly* rotation upon its common center of gravity corresponds to the rotation of the small turntable. The *annual* revolution of the earth-moon system around the sun is represented by the rotation of the large turntable, and the *daily* rotation of the earth upon its axis duplicates the rapid rotation of the disc around its center.

We shall now review the four experiments above in their order but with reference to the actually observed phenomena.

1. The earth and moon constitute a binary system which revolves around its common center of gravity (the pivot). This monthly rotation obviously produces a bulge in the earth with the long axis constantly in line with the earth's center, the pivot and the moon precisely as in experiment 1. This bulge is not produced (as the writer sees it) by the moon's unequal gravitational force upon the near side, central core, and far side of the earth as is universally stated. The only part that the moon's gravitation plays is to *help fix the position* of the pivot or common center of gravity. Centrifugal force due to rotation causes the bulge *regardless of the type of motive power producing the rotation, even to the entire exclusion of the moon.* It may be remarked here that if the earth and moon were independent spheres and without mutual rotation there would be no bulge in the earth since spheres "attract and are attracted precisely as if the matter in them were wholly collected at their centers." (C. A. Young, "General Astronomy," paragraph 162.) Even if they were a rotating binary but of such masses and distance apart as to place the pivot outside the earth, as in Fig. 9, there would be, for the same reason, no bulge in either sphere. This statement is supported by the following experiments: First, suspend a sphere of flexible material, as rubber, by a cord attached at a point on the surface. The earth's gravitation will distort the sphere into an ellipsoid. Fig. 10. Second, suspend the sphere again but with the cord attached at a point within the sphere about half way between the center and the surface. Again the sphere will be distorted but to a lesser degree. Fig. 11. Third, suspend the sphere with the cord attached at the center. No change in form will take place. It will remain a sphere. Fig. 12. The same results would be obtained if the sphere were twirled around a pivot as in Fig. 9.

2. The actual phenomena corresponding to the large turntable consists in the annual revolution of the earth-moon system around the sun. The gravitational force of the sun acts upon this *binary system* "precisely as if" all the matter in both spheres were concentrated at the pivot or common center of gravity. To illustrate, join two balls of unequal weight by a rigid bar so that the balancing point falls within the larger ball. Now suspend or twirl this bar by a cord attached at this balancing point. Obviously the pair will remain at rest in any position or rotate freely in any direction. This view is supported by the following quotation from Young's "General Astronomy," paragraph 243: "It is this common center of gravity of the two bodies [earth and moon] which describes around the sun the ellipse which we have called the earth's orbit." Since the rotation of the earth-moon binary fixes the common center of gravity at one side of the earth's center, and since the sun's gravitation attaches as if at that point, we may, for the present purpose, remove the moon and the resulting phenomena will duplicate experiment 2, the result being a bulge with the long axis constantly in line with the

earth's center, the pivot and the sun. Fig. 4.

3. The combination of the two turntables has its counterpart in the conjunction of the two movements—the earth-moon system rotating *monthly* around its common center of gravity and the revolution of this system *annually* around the sun. The resulting composite bulge in the earth will differ from that in the experiment because of the inequality of the two centrifugal forces, that of the earth-moon being greater than that of the sun. We shall now compare the actual phenomena with the four stages of experiment 3.

a. At the first stage the two forces are acting in unison and in the same direction (outward, at new moon), hence the greatest bulge possible, although this bulge will not be twice that produced by the earth-moon force alone.

b. At the second stage, when the moon is in quadrature, the two forces act at right angles to each other thus reducing the bulge to the least possible dimension although the earth will not be reduced to a perfect sphere as in the experiment because the forces are unequal.

c. At the third stage or full moon, the two forces again act in unison, but in opposite directions, producing again the greatest bulge (Exp. 3, Sta. 3).

d. At the fourth stage or quadrature the bulge is again its least and the earth attains its nearest approach to a perfect sphere as in the second stage. Upon complete rotation the conditions at the first stage will be repeated.

4. It may be noted that up to this point in our explanation no mention has been made of tides. As previously stated the cause of tides is not the primary problem. When the causes contributing to the earth's varying bulge are determined, tides follow as a necessary consequence. This consequence is due to the *daily* rotation of the earth *upon its axis* and the *mobility* of the waters of the ocean.

The daily rotation of the earth upon its axis is the exact counterpart of the rapid rotation of the disc on its center in experiment 4, and it is here that we are brought, for the first time, to a consideration of the immediate cause of ocean tides.

Proceeding now upon the foregoing foundation we must note again that the earth is not a disc of pliable rubber but a sphere (ideal for simplicity) of solid material covered with a concentric sphere of water of uniform depth and with the sun and moon in the plane of the equator. It is this layer of mobile water which responds to the two centrifugal forces by rising and falling *in the same manner* as the flexible material of the disc in experiment 4. Since the centrifugal force of the lunar rotation is greater than that of the solar the two daily high tides always follow (theoretically) directly under, and on the opposite side from, the moon.

At the time of new moon these two high tides (on opposite sides of the earth) reach their greatest elevation during the month (Exp. 3, Sta.

1) and are known as *spring tides* while the intermediate low tides reach their lowest point. As the earth-moon rotation slowly proceeds the daily high tides gradually become lower for about a week when the moon arrives at quadrature (stage 2). At this point high tides are at their lowest and are called *neap tides*. During the same period the daily low tides gradually rise until at quadrature they reach their highest point. During the succeeding week the high tides gradually rise until at full moon they again reach their highest (spring tides—stage 3) and the low tides are at their lowest. A third week brings again the low highs (neap tides—stage 4) and the high lows. At the end of the month or complete rotation of the earth-moon system the spring tides again occur. Expressed in another way the greatest difference between the daily high and low tides is at spring tide, or new and full moon, and the least difference is at quadrature.

In the preceding argument it has been shown that the phenomena of a constantly varying bulge in the earth (the tides), resulting from the revolving movements of the sun, earth, and moon duplicate a series of laboratory experiments. In these experiments surely no question can arise as to the cause of the varying bulge in the disc, namely: the combination of two centrifugal forces. Why, then, should any other cause be attributed to the like phenomena observed in the system of the sun, earth, and moon? No direct "attraction" or "pull" appears to enter into it. If the turntables in the third experiment were not rotating there would certainly be no bulge in the rubber disc and likewise, if the sun, earth, and moon were independent spheres and at rest there would be no bulge in the earth and no tides. It may be pertinent to ask: if gravitational pull causes the tides what does the counteracting centrifugal force do?

Throughout this discussion ideal conditions have been presumed in order to present fundamental principles. It is well understood, however, that many irregularities and obstructions modify the results obtained by theoretical considerations such, for example, as irregular coast lines, bays, inlets, islands, continents, varying depths of the oceans, variation in the declinations of the sun and moon, eccentricity of the orbits of the earth and moon, etc. These many irregularities make the actual observed phenomena of tides in different localities so widely variant from the ideal that the fundamental principles involved are obscured almost beyond recognition.

In the foregoing presentation of this theory some queries have doubtless arisen, for example: why the daily inequality of the high tides? why the difference in time between high and low tides? why does high tide sometimes precede and sometimes follow the moon's crossing of the meridian? These questions are reasonable and must, of course, be answered. In the discussion that follows an attempt is made to answer these questions and show by appropriate illustrations the application of this theory to the observed phenomena of tides.

Among the causes of tidal variation mentioned above two are astronomical in character, namely: declination and eccentricity. The first will be considered in some detail in explaining the chief irregularities in tides. At the outset let it be recalled that the lunar and solar centrifugal forces distort the earth into an ellipsoidal form. This form is represented in Fig. 13 with the sun and moon in the equatorial plane and in Fig. 14 with the sun and moon in line with the earth but far out of the equatorial plane. These diagrams are greatly exaggerated in order better to visualize the points under consideration.

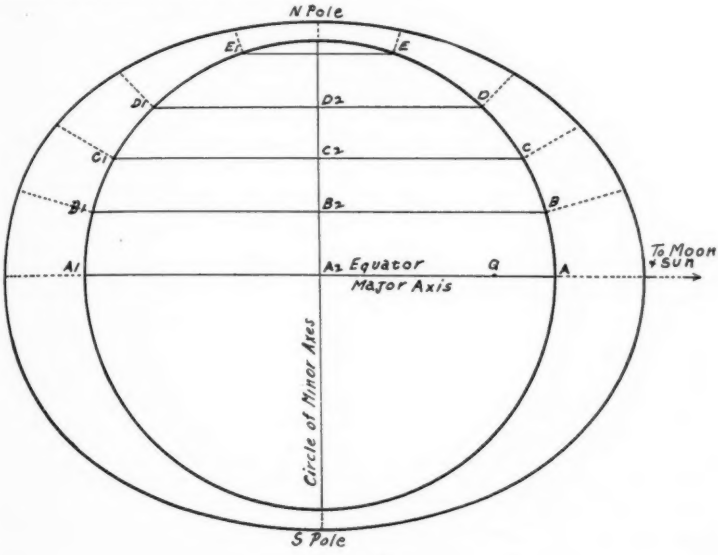


FIGURE 13

In referring to these diagrams keep in mind that *high tides* always occur at the *ends of the major axis* of the ellipsoid and *low tides* occur on the circle joining the *ends of the minor axes*. Also, for convenience and greater simplicity the observer is presumed to be on the solid sphere (at the bottom of the ocean) and the dotted extensions of the earth's radii represent the depth of the water above him. It may be further noted that while these figures are made on a flat surface they really represent a *solid ellipsoid* so that such letters as C2, for example, locate two points on the surface, one on the near side and the other on the side opposite. It may aid the reader to have in view a melon or symmetrical egg to better visualize the ellipsoidal form of the earth and the curvature of the parallels. G locates the common center of gravity of the earth-moon binary system.

With this preliminary monition let us proceed to a more detailed con-

sideration of the numerous variations in ocean tides according to the theory herein presented.

Fig. 13 represents the ideal earth at the time of new or full moon when both sun and moon are in the plane of the equator. The major axis of the ellipsoid is in line with both bodies and high tides at A and A1 are directly under and opposite the moon. These two opposite tides are obviously equal in height and twelve hours apart. North or south of the equator, as at B and B1, etc., high tides are also equal and twelve

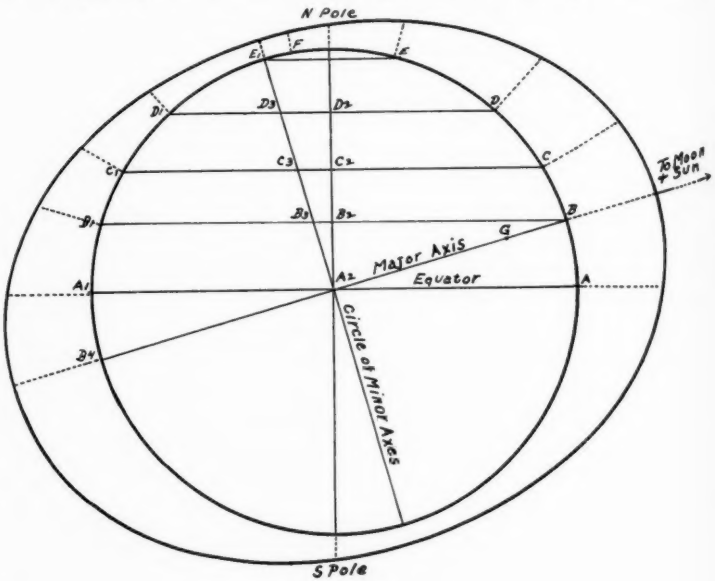


FIGURE 14

hours apart but of uniformly diminishing height in going from the equator to the poles. Low tides on the circle in the middle of the ellipsoid (vertical line in the figure) as at A2 (near side) and A2 (far side), etc., are equal and twelve hours apart with unvarying height toward the poles. There is no tide at either pole.

A study of Fig. 14 will aid in the explanation of a number of tidal anomalies. The chief astronomical cause of variation in the height of tides is the changing declinations of the sun and moon. At the summer solstice, June 21, the sun is farthest north. If the moon has the same north declination on this date and it is new or full moon the lunar and solar centrifugal forces will be acting in unison and the earth will have its greatest bulge or the longest major axis of its ellipsoidal form (subject to eccentricity to be explained later). This is the status represented in Fig. 14.

It is evident that the opposite high tides at B and B4 are equal, being at the ends of the major axis. At B high tide is the highest possible but at B1, on the opposite side of the earth, *on the same parallel* high tide is not so high as at B. The same is true of C and C1, etc., both tides diminishing as we proceed toward the poles. This variation is known as "diurnal inequality."

It will be seen from Fig. 14 that high tides *at the equator* are always equal regardless of declination and the direction of the major axis, the ends of which are always equally distant north and south of the equator, as from A to B and from A1 to B4. These tides are subject to constant, though slight, irregularity in height because of the constant change in declination.

It may be well to point out here that when the declinations of the sun and moon are unlike (they may be as diverse as 23 and 28 degrees on opposite sides of the equator) the lunar rotation *tends* to bring the major axis of the ellipsoid in line with the moon while the solar rotation *tends* to bring it in line with the sun. There cannot be two ellipsoids, hence the major axis must take a direction between the two component forces. This shifting of declinations results in a continuous and irregular variation in the length of the major axis and therefore in the height of the tides. Low tides will be similarly, though less affected since, when the major axis lengthens the minor axis shortens, and *vice versa.* Briefly, as high tides increase low tides diminish and as high tides diminish low tides increase.

Not only do the changes in declination give rise to variation in the height of tides but this astronomical cause also accounts for the difference in time between tides. Observe again that high tides occur at the ends of the major axis of the ellipsoid and low tides occur on the circle joining the ends of the minor axes. It will be obvious from Fig. 14 that high tides are always twelve hours apart and as we go from the equator toward the poles this twelve hour period becomes more and more unequally divided by the circle of the minor axes. The time between low tides therefore varies from zero to twenty-four hours (depending on latitude) and the time between a high and a low tide varies from zero to twelve hours. These facts will appear more clear if we suppose the observer starts at C where it is high tide and travels on that parallel to C2 (ignoring axial rotation). He will have gone one quarter of the distance around the earth in six hours but it will not be low tide there. He must continue, say one hour, to C3 which is on the circle of the minor axes where it is low tide. Traveling five hours more he arrives at C1, opposite C, where it is high tide again.

From this example we see that the time from the first high tide (C) to the second high tide (C1) is twelve hours. From the first high to the first low (C3 near side) is seven hours. From the first low to the second high is five hours. From the second high to the second low (C3 far side) is five hours and from the second low to the third high is seven

hours. Also the time between the two low tides around the short end is ten hours and around the long end is fourteen hours.

If this example is applied at B, D, and other points there will be corresponding variations but of different degrees. Note, however, the situation at E. The observer starting at E (high tide) will travel on that parallel twelve hours to E1 which will be at the second high tide. This point will also be on the circle of the minor axes, therefore the second high tide and the two low tides will coincide. In other words all three

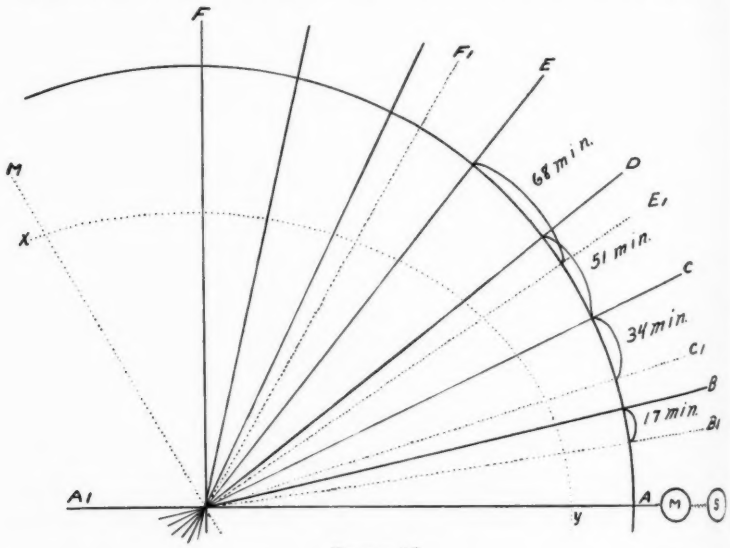


FIGURE 15

EXPLANATORY: A-A1 represents the line of the major axis of the ellipsoidal earth (x-y) at new moon. The convenient quadrant from A to F is divided into seven equal angles to represent the moon's daily advance through its first quarter of one week. All other radial lines represent the directions of the major axes of ellipsoids with the boundaries omitted.

tides disappear. Beyond this point, as at F, there will be no tide in the usual sense but a gradual rise of the water for twelve hours followed by a gradual fall for the same period. As the declinations change, the circle of the minor axes will oscillate irregularly between E and E1. Thus all four of the usual tides will occur with slight irregular variations up to the latitude of the minor axes circle. There can be no daily tides at the poles but there will be constantly a very slight, slow, irregular rise and fall of the water due to the changing declinations of the sun and moon.

The other astronomical cause which affects the height of tides is the eccentricity of the orbits of the moon and earth. The moon's orbit is an ellipse and the earth is situated in one of the foci, which conforms to

Kepler's law of all planets and satellites in the solar system. As the moon revolves around the earth it moves *faster* than the average around the short end (in perigee) and *slower* around the long end (in apogee). This accords with Kepler's second law. The greater velocity of the moon in perigee increases the velocity of the earth's rotation on the common center of gravity, hence an increased centrifugal force resulting in a greater bulge and in a higher tide. Similarly, a lower tide results when the moon moves at a slower rate in apogee. The same conclusion follows from the eccentricity of the earth's orbit around the sun but to a lesser degree.

Another apparent anomaly relating to tides is that high tide rarely occurs at the time the moon crosses the meridian. It may precede the moon's transit in which case it is known as the "prime" of the tide or it may follow when it is known as the "lag" of the tide.

In any general theory spring tide should occur when both sun and moon are on the meridian, that is at new (or full) moon, and neap tide should occur when the moon is in quadrature. This phase of the subject is somewhat complicated and a critical reference to Fig. 15 will aid materially in its understanding. Note first the explanation on the diagram. When the sun and moon are in line with the earth as at A the two centrifugal forces are acting in accord and the major axis is extra long. At this time high tide is on the meridian directly under the moon.

At the end of one day the moon will have moved to B and the lunar rotation will *tend* to produce an ellipsoid with the major axis at line B. With the sun remaining practically stationary (change in seven days would be negligible), the solar rotation will *tend* to produce an ellipsoid with its major axis at line A. Since there cannot be two ellipsoids, as previously noted, the resultant of the two forces will be a slightly shortened ellipsoid with its major axis at B1. Since the lunar centrifugal force is about twice that of the solar the line B1 falls nearer to B than to A, say about one third of the distance from B to A. Recalling now that high tide must occur at the ends of the major axis it will be seen that here high tide *trails* the moon and reaches B1 at the time the moon reaches B. How much is this lag? The moon has moved for one day through one twenty-eighth part of its entire orbit. During this one day the major axis has fallen back one third of this distance or one eighty-fourth part of the whole circuit. The moon would have to move around its orbit three times in order for this daily lag to amount to a whole day, therefore the falling back of the major axis on the first day is represented in time by one eighty-fourth part of twenty-four hours or about seventeen minutes, the amount of retardation or lag which is represented in the figure by the curve B B1.

During the second day the moon will have moved to position C but the resultant major axis will have fallen back one third of the distance from C to A, or to the line C1. The lag on the second day will be twice that on the first day, or thirty-four minutes. On the third day the moon

reaches D. The lag is again one third of the distance from D to A and the major axis falls at the line C. The lag is three times that on the first day or fifty-one minutes. The fourth day finds the moon at E with the lagging major axis and high tide at E1 and the lag is sixty-eight minutes.

It will be noticed that if this progressive regularity continues until the moon reaches first quarter at F the major axis will presumably fall at F1, one third of the distance from F to A. This will be impossible, however, since, when the moon is at quadrature the two centrifugal forces act at right angles to each other and the resultant major axis might fall at line M as well as at F1. As a matter of fact the major axis must be at F, the direction of the stronger force. The tide catches up with the moon and occurs on the meridian exactly under the moon. The solution of this anomaly appears to the writer as follows: It is obvious from both theory and observation that during this seven-day period from new moon to first quarter high tide does lag. It is equally obvious that this increasing lag must, in some way, diminish so as to disappear at first quarter. It would seem that retardation increases gradually for a time —possibly to the third or fourth day—when it reaches the maximum and then decreases gradually through the remainder of the period and evanesces at the meridian on the seventh day. If we assume, arbitrarily, that the figures stated for the first four days are correct and that on the fifth day the lag is forty minutes and on the sixth ten minutes the average lag during the seven days is about thirty-one minutes, which is quite consistent with Young's conclusion—"about half an hour" ("General Astronomy," paragraph 470).

When the moon passes first quarter and moves toward full moon this procedure is reversed. High tide *precedes* the moon and accelerates to its maximum about the third or fourth day and then gradually decreases its acceleration until it evanesces on the meridian at full moon. The third and fourth quarter periods duplicate exactly the first and second periods, respectively.

This lagging and priming of the tides may be better understood if the reader will completely renounce the idea that the sun and moon are forces out in space "pulling" by gravitation upon *different parts* of the earth. The so-called "tide-raising" forces are, in the writer's view, no more, no less, than the two centrifugal forces within the earth itself operating jointly upon the waters of the oceans.

The foregoing explanation of the variance in tides due to declination and eccentricity does not solve all the problems concerning tides. There are many apparent anomalies in the behavior of large bodies of water which are not thus accounted for, for example: in the Bay of Fundy, the Maelstrom, Deception Pass, etc. If the floor of our ideal ocean were ruffled up so as to greatly vary the depth of the water, with some parts protruding above the surface forming islands and continents, and if we introduce winds, cyclonic storms, earthquakes, etc., it is obvious that the

tides produced under theoretical conditions would be much disturbed and modified in certain regions. The tidal problems involved at any place must be worked out under the conditions prevailing in that vicinity. No general law can possibly apply to all the erratic situations found throughout the world. These conditions are terrestrial and vary chiefly with the geographical character of the locality and the resulting irregularities in tides are wholly apart and distinct from those which are due to astronomical causes.

Most of the tidal records made throughout the world covering many years of observation are made within arms of the sea or in straits leading into them. However important and valuable these observations may be for the "establishment of the port" or other purposes, they avail little in testing the correctness of any general theory on the cause of tides. Typical of the regions to which this remark applies are the Golden Gate, leading to San Francisco Bay; the Strait of Juan de Fuca, leading to Puget Sound; the Narrows, leading to New York Harbor; and the Bay of Fundy. Let us examine the case of San Francisco. If the California coast were an unbroken cliff high water would be practically uniform all along the coast and would probably occur about on astronomical schedule. The Golden Gate forms a narrow opening, however, which permits the rising water to *flow* through into the bay by reason of the earth's gravitation. This water mingles with the water of the bay and must ultimately flow back through the same channel. Clearly it is physically impossible for this flow and ebb to take place on anything like schedule time. In consequence of these conditions high water at Fort Point would be far from normal, which accords with actual observation. The same reasoning holds for Seattle, New York, or any other place where the bay has a narrow entrance and especially if there is a long coast line and the water area is broken by numerous islands and peninsulas. The most suitable place to test any general theory on tides would seem to be at a small isolated island rising abruptly from deep water in mid-ocean.

Perhaps the most important problem concerning tides from the practical point of view is: how does this or any other theory aid in the prediction of the time and height of the tide? Under the prevailing theory this is approximated chiefly by averaging many observations, and one important result of this procedure is known as the "establishment of the port" which is defined as "the mean interval between the passage of the moon across the meridian and the time of the next high water at that port on the days of new and full moon, used as a basis for the computation of the tides." ("Standard Dict.")

This "establishment" is inadequate since it refers only to spring tides (two days in the month), the figure is an average, and the prime and lag are not taken into account. It is desirable, however, to know the time and height of high tide at any place on *any day*. Under the theory here advocated five positive factors enter into this problem, namely: 1. declination of the sun, 2. position of the earth in its orbit, 3. declination of

the moon, 4. position of the moon in its orbit, 5. latitude. The date alone will determine the first two factors. The third and fourth may be obtained from the nautical almanac, and an ordinary map will show the latitude.

From these data the mathematician may calculate both the time and the height of high tide for the designated place and date—on the basis of the "ideal" earth. The results thus obtained must be modified as required by a sixth factor, namely: terrestrial conditions. These conditions are largely local and geographical and therefore practically constant. Thus the results obtained by the "ideal" calculations for any day will always be modified by about the same amount.

Some authorities on tides dwell much upon the "tide-raising forces" and show by formulae and involved calculation that these forces are inversely proportional to the *cube* of the distance from the earth to the moon. (Darwin, "The Tides," Chap. V. Young, "General Astronomy," paragraphs 464-466.)

Perhaps a simple illustration will serve the same purpose.

Let us suppose the moon's orbit is a circle (designated A) with the earth at the center.

1. In this position the gravitational and centrifugal forces are equal since the moon revolves in this fixed orbit.

2. If the moon is moved to an inner circle (designated B) one half the distance from the earth, the gravitational force will be four (the inverse square of one-half) times the force at A.

3. The centrifugal force at B must also be four times that at A, to hold the moon in this fixed orbit.

4. The moon at B must revolve around the earth *twice* (the circle at B is half the circle at A) to equal the velocity and centrifugal force at A.

5. The moon must therefore revolve around the earth *four times twice* or eight times to equal the gravitational force at B.

Eight is the inverse cube of one-half. The same logic would apply if B were one-third, one-fifth or any other part of the distance from the earth to A.

In conclusion we may summarize this "new theory," or perhaps better, "centrifugal theory" on tides as the antithesis of the "gravitation theory" which has prevailed universally since the time of Newton. The forces ascribed to the cause of tides in the two theories, respectively, are equal and opposite, thus counterbalancing each other. From this it would seem that all mathematical results would be precisely the same regardless of whether the mode of calculation were based upon gravitation or upon centrifugal force.

South High School, Minneapolis, Minnesota,
October 29, 1940.

The Brown University-Skyscrapers Eclipse Expedition to Brazil

By CHARLES H. SMILEY

To send a small party to Northern Brazil to photograph the total solar eclipse of October 1, 1940, the members and friends of the Skyscrapers, amateur astronomcial society of Rhode Island, generously provided funds supplementing those made available by Brown University. The principal purpose of the expedition was the verification of results obtained by the Brown University expedition at the eclipse of June 8, 1937, in Callan, Peru. An attempt was to be made to photograph the outer corona as well as the Zodiacal Light in the vicinity of the sun.

In addition to the f/1 Schmidt camera of four inches focal length which had been used in 1937, an f/3 Schwarzschild camera (effectively f/3.5) of thirty-six inches focal length was to be used. The latter camera, the second of its kind, was constructed by members of the Skyscrapers during 1939-40. Its twelve-inch primary mirror, approximately hyperboloidal in shape, was ground, polished, and figured by Arthur A. Hoag. The six-inch secondary, approximately ellipsoidal, was made by the author of this article. A splendid, rugged, closed-fork type, equatorial mount was constructed in cast aluminum by J. Frank Morrissey and W. Edwin Stevens while an aluminum camera tube was provided by Harry A. MacKnight. A clock-drive of novel design was constructed by H. A. MacKnight and F. W. Hoffman.

The party consisted of Dr. Alice H. Farnsworth of Mt. Holyoke College, Arthur A. Hoag, an astronomy student at Brown University, and the author. Dr. Farnsworth, on sabbatical leave from Mt. Holyoke, was preparing to go to South America to make spectrographic studies of the light of the night sky; the eclipse was merely a secondary object for her. Mrs. Smiley had planned to go but serious illness in her immediate family necessitated a change of plans at the last moment.

The party sailed from Hoboken on August 24 on the same freighter that carried the six members of the National Geographic Expedition. The nine scientists made up the entire passenger list. Ten pleasant days brought the ship to Recife, capital city of Pernambuco, where both parties disembarked. Customs officials granted us the courtesy of the port which simplified considerably our entry into Brazil. On checking our baggage, it was found that the large box containing the equatorial mount was missing. After a long search, it was found still aboard the ship; it was removed about half an hour before the boat sailed for points south.

From the moment of our arrival until we sailed north again, we were made to feel that we were among friends. We enjoyed especially the privilege of meeting the Interventor of Pernambuco, Agamemnon

Magalhaes. We must not fail to mention the generous hospitality of the Mayor of Recife. For many kindnesses we are particularly indebted to Dr. and Mrs. L. M. Henderlite of Recife.

The party accepted the invitation of Dr. Estevam Marinho, an engineer of Brazil's splendid department of drouth control (*Inspetoria Federal de Obras Contra as Secas*, often abbreviated as IFOCS), and made the IFOCS guest house at Curema, Parahyba, its headquarters. For transportation of ourselves and our equipment 250 miles inland to Curema and return and for a thorough-going hospitality during the three weeks spent at Curema, we are indebted to the IFOCS and especially to our host, Dr. Marinho.

Though our site, latitude 7° 01′.8 south, longitude 37° 57′.8 west, was 27 miles south of the central line of the eclipse path and the duration of totality 256 seconds instead of 282 seconds, the modern conveniences at Curema such as electricity, refrigeration, running water, comfortable housing, swimming pool, and flood-lighted tennis courts recommended it above any other site. Cement piers were erected for our instruments by IFOCS workmen.

The heavy equatorial mount carried, in addition to the Schmidt and Schwarzschild cameras, the night-sky spectrograph which Dr. Farnsworth was using. The assembly, adjustment, and testing of the equipment required most of the available time. In the eighteen days immediately preceding the eclipse, thirteen were "satisfactorily clear" at eclipse time.

The first of October was beautifully clear at dawn. By the time of first contact, there were some clouds in the sky but not enough to interfere with the timing of that contact. The clouds grew steadily thicker, completely covering the region of the sun a few minutes before totality and not breaking again until after totality was over.

The exposures were made just as if there were no clouds, five with the Schmidt, twelve with the Schwarzschild, and one with the spectrograph. It was the first and only time that the entire program had gone through without an error of any sort, all to no avail! All films were standardized but the photometric results obtained have little or no value.

On the second of October we were packed up and on our way to the coast. Dr. Farnsworth sailed for Rio de Janeiro on the third but Mr. Hoag and I were obliged to wait until the twentieth for a boat to take us to New York. The ship on which we had booked passage cancelled its call at Recife and went instead to Bermuda to carry British gold to Boston.

Though we were clouded out on eclipse day, the expedition was not a complete failure. We took advantage of our excellent opportunity to observe the Zodiacal Light away from the sun. We also observed many interesting celestial objects of the southern skies with a six-inch reflecting telescope which had been made for us by the Skyscrapers. This telescope, as had been planned, was left as a good-will gift at the Escola

de Engenharia de Pernambuco in Recife.

In saying goodbye to our Brazilian friends, we expressed the hope that we might return to the same region in 1944 to observe the total solar eclipse of January 25.

BROWN UNIVERSITY, FEBRUARY 15, 1941.

Artificial Eclipses of the Sun*

By DONALD H. MENZEL

In November and December of last year, a series of astronomical talks was given by radio from the stations WRUL and WRUW. The series was planned and announced by Dr. Zdenek Kopal of the Harvard College Observatory. Through Dr. Kopal's assistance we are to have the privilege of publishing several of these talks. This is desirable because on the one hand it gives our readers the benefit of these discourses even though they may not have heard the broadcasts, and on the other hand it puts this material into form so that it may be referred to from time to time. The following paper was broadcast on November 23, 1940.—EDITOR.

These programs from Station WRUL and WRUW are coming to you through the courtesy of the sun. Yes. I mean that literally. For radio waves, like light waves, tend to travel in straight lines, and could not possibly bend themselves around the curved surface of the earth if it were not for the presence of a great mirror in the atmosphere high above the surface of the earth. This mirror consists of a layer of fragments of atoms, atoms that have had electrons torn from them by the action of sunlight. Now, an ordinary mirror depends for its reflectivity, not upon the hardness or apparent solidity of the material, but upon the fact that there are a lot of free electrons floating around through any metallic surface. It is to the electrons, then, that we ascribe the properties of reflection. And these electrons in the upper atmosphere, or, as the physicists call it, the ionosphere, are capable of reflecting radio waves in the same fashion that an ordinary mirror reflects light.

If the sun were to cease shining, the atomic fragments would join, the electrons would disappear, and we should then have no more reflecting layer. You would be unable to hear this program because the waves from the sending station would not reach any receivers beyond the optical horizon.

In next week's talk, Dr. Harlan Stetson is going to speak about the details of solar radiation and radio reception. For this reason, I shall not enter into any lengthy discussion of the subject. I merely wish to

*In preparing this radio talk, I abstracted freely from my leaflet, No. 139, published by the *Astronomical Society of the Pacific*.—D.H.M.

point out that any change in the quantity and quality of the solar radiation may have a corresponding effect upon the ionosphere, and, therefore, upon radio reception. The world-wide paralysis of communication services last Easter Sunday, which most of you recall, was undoubtedly caused by electric particles that were ejected by the sun, and guided earthward by the magnetic field of an enormous sun-spot group. For the sun also ejects atoms as well as radiation. And both of them have effects on the earth.

During the time of the magnetic storm last Easter, the solar electrons, bombarding the earth, produced brilliant auroral effects in the upper atmosphere. The extra electrification was so intense that radio waves were deflected from their normal paths. Further, as the charges approached the earth's surface, they induced stray electric voltages in communication lines, blew fuses at random, and isolated various areas of the country.

How does the sun produce such effects? It is well known that the sun is surrounded by an envelope of streamers, the solar corona, which is generally visible only at the time of total solar eclipse. Last week a number of eclipse observers got together over this station and discussed some of the problems of direct eclipse observation. We then mentioned the importance of study of the corona. Apparently what happened on Easter last was that the earth passed through the end of one of these coronal streamers. If we had been able to observe the corona from day to day, we might have forecast the disturbance, and, perhaps, even have prepared for it.

Solar eclipses, from the standpoint of the astronomer, are all too rare a phenomenon. For years we astronomers have been traveling to the ends of the earth, chasing eclipses, with the desire of photographing and studying the corona during those few minutes of totality. And then there is a wait of several years for another chance to continue the investigation of the sun's mysterious aura. Small wonder that knowledge of the corona has been slow in accumulating! If only we could observe it from day to day! Fortunately, a new instrument, known as the coronagraph, should make such regular observations possible.

Invented and developed by Dr. B. Lyot in the Observatory of the Pic du Midi, in French Pyrenees, the coronagraph gives great promise of furnishing us with a solution of many important solar problems. One of these instruments, perfected over the past three years at the Harvard Observatory, has just been installed on Fremont Pass, Climax, Colorado. Located at an altitude of 11,500 feet, the new solar station is the highest astronomical observatory in the world, and contains the only coronagraph in America.

Observation of the solar corona without the intervention of an eclipse requires the clearest skies and the most highly perfected instruments. No ordinary sky will suffice for the problem. The atmosphere must be especially free from dust and from small suspended particles. Even a

minute trace of dust produces a hazy solar halo of atmospheric origin that entirely masks the faint corona. The corona is always there; as a matter of fact, its total brilliance is about equal to that of the full moon. Our inability to see it ordinarily comes merely from the fact that the surrounding sky light is too bright to render it visible. We have no difficulty in seeing the moon in the daytime as long as it is some distance away from the sun. From the astronomical point of view, the trouble with the corona is that it is attached to the sun.

The possibility of observing the corona without the assistance of the moon has been the astronomer's dream for many years. Many methods have been tried. I understand that the astronomer Langley, in observing a total eclipse of the sun from the summit of Pike's Peak, was so impressed during totality by the great brilliance of the corona that he hoped to be able to see it again the next day. Thus, standing on a somewhat lower level, as the sun rose over the top of a high cliff, he attempted to make out the outline of the corona. Unfortunately, he could detect none of the brilliant streamers that he had so clearly seen the day before.

There was also the obvious method of trying to make an artificial eclipse of the sun inside of a telescope. At the focus of the main lens, where the images of the sun and, presumably, also of the corona are formed, one may insert a blackened disk, like an artificial moon, to cut out the brilliant sunlight, and then photograph the solar corona with a second camera placed back of the disk. Alas! such observations also came to naught.

Pictures were secured, it is true, and many of them showed peculiar structures, but the blackening was due chiefly to the illumination of the brilliant sky. And the ray patterns present were caused by reflections in the lenses, or scattered light from the wall of the tube. These streaks are similar to those that the amateur photographer may get in some of his pictures when he accidentally points his camera in the general direction of the sun. Many astronomers thought that the situation was hopeless, and concluded that the problem was insoluble. One even rashly said so in print.

The advent of infra-red photography presented a new possibility. The penetrating power of the longer light waves was demonstrated. Distant mountain ranges, almost invisible in the atmospheric haze, could be clearly photographed. But this glimmer of hope also faded when it was realized that the interfering halo of sky was white, not blue, and therefore could not be filtered out.

There are, therefore, two factors to be taken care of if we are ever to achieve coronal study outside of total eclipse. We must have this blue sky, right up to the edge of the sun, and scattered light in the instrument must be completely eliminated. Try the following experiment yourself, sometime. Stand inside the shadow of a building or a porch and walk toward the sunlight, keeping your eyes on the sky all

of the time. The chances are that the sky will become uncomfortably bright long before the sun itself actually appears. You will have no difficulty at all in telling exactly where the sun is located.

This white ring is caused by the dust, smoke, water droplets, etc., that are in the earth's atmosphere. Even insects and high-flying dandelion seeds present difficulties. When sunlight strikes any of these objects, it is deviated only slightly from its normal path. Therefore, as we look toward the sun, we perceive the deflected rays as a bright halo that effectively extinguishes the fainter corona behind.

Now, imagine an atmosphere washed clean of all foreign matter. Theoretically, the sky would then be only twice as bright at the solar limb as at a distance ninety degrees from the sun, and with a sky of this character one should have little difficulty in recording the structure of at least the inner corona.

At high altitudes in areas where heavy rains are frequent, the sky begins to approach these ideal conditions. Prevailing winds are also important, because high-flying dust, borne from great distances, may cause interference. One of the highest observatories in the world is located on the Pic du Midi, in the Pyrenees on the southern border of France, and it was there, about 1930, that a young Frenchman, Dr. B. Lyot, took up the coronal study. A check showed that the sky there was very nearly perfect.

Some of the preliminary observations were made visually. Dr. Lyot found that he could very definitely detect the corona. And then, he turned his attention to the difficult problem of designing a perfect instrument. Recalling the difficulties that his predecessors had with reflected light inside the instrument, Dr. Lyot procured a primary lens of almost perfect purity. Bubbles or fine scratches on the surface, all of which scatter sunlight, he scrupulously avoided. To discourage dust from depositing itself on the inner surface of the lens, Lyot coated the inside of his telescope tube with sticky grease, to entrap any flying particle of dust. He used diaphragms and baffles in strategic positions to cut down the light scattered inside the instrument. The disk that he used to hide the sun had an inclined mirror surface in front, which reflected most of the unwanted sunlight outside of the tube. Installing the apparatus on the isolated peak was difficult and hazardous. With the instruments strapped on their backs, the men ascended on skiis and snow shoes. Part of their trail lay over cliffs, where anchored cables assisted them, but the coronagraph was finally set up and observations begun. I shall refer later to the nature of Dr. Lyot's work. His results seemed so significant to us at Harvard that we decided to build one here.

I considered many sites before I finally selected Fremont Pass for the Harvard Station. It was evident that frequent heavy rains were desirable, which would wash the air clean at intervals. Fremont Pass, on the Continental Divide, about thirteen miles from the old mining town of Leadville, proved to be an ideal location. With violet-clear sky,

it combines the desirable features of all-year-around accessibility, electric power, and water supply. The project was made possible through the interest and coöperation of the Climax Molybdenum Company and its directors. The Observatory was built on the property of this company. A large mine, the largest molybdenum mine in the world, is located here, and its many facilities make it possible for the observer to withstand the rigors of the winter at an excessively high altitude.

The coronagraph itself is a special kind of telescope in which an eclipse of the sun is artificially made. There is a simple lens out in front, to form an image of the sun and of the sky immediately surrounding it. Right at the focus is placed a small disk, about the size of a twenty-five cent piece, to blot out the bright solar image. The remaining radiation from the sun's corona and the geyser-like prominences that are also seen, jutting out from the solar limb, are then photographed directly with the second camera lens. There are numerous ways in which we can study the radiation. One consists of a powerful spectrograph for the study of the spectrum of the corona, in analysing the colors of its radiation. Also, we are making studies of the motions of solar prominences and, we hope, also of the corona with color filters and with motion-picture technique. The procedure is of some interest, and I shall describe it a little more fully.

With the motion-picture camera we take about one frame, that is, one picture, about every half minute. During projection, this picture appears on the screen for only a twentieth of a second. In effect, there is a speeding up of about six hundred times between the taking of the picture and its projection rate. Thus, an entire day's observations, consisting of about ten hours, or six hundred minutes, will appear in one minute on the screen. As a result of the increased speed of projection, the slow stately motions of the sun's atmosphere are exaggerated and more clearly depicted.

Prominences, which are flame-like projections jutting out from the surface of the sun, form a particularly striking exhibition. We see that the sun is in a state of violent turbulence. Nowhere is it steady, even for a moment. We, who on earth think that a wind of ninety miles an hour is a hurricane, should look to the sun, where ninety miles an hour is almost pure stagnation—a gentle breeze. On the sun, gales of ninety miles a second are far from uncommon.

The motion-picture technique shows that many varieties of prominences exist. I should mention that they are not really flames, in the sense that they represent something burning. For the sun is too hot to burn. "Burning" is a process that requires chemical combination, an atom of carbon uniting, say, with an atom of oxygen. On the sun, such a chemical reaction would proceed in the opposite direction. Carbon dioxide, the common product of combustion here on the earth, would be broken up in the intense heat of the sun's atmosphere. The "flames" are actually great clouds of luminous gas, some of them many hundreds

of times larger than the earth in size.

A number of varieties of prominences exist. Some look like fleecy summer clouds, slowly changing their shapes as they hang high above the surface of the sun. Others, more active, look like great fountains, playing enormous jets of gases to great heights. From some of the suspended clouds material streams downward, like rain, to the solar surface. Only, of course, it is not rain, but gaseous iron, hydrogen, and all of the other substances well known on earth. Then, there are the enormous eruptive prominences, which explode with great violence, hurling masses of gas far out into space. All of these motions are clearly depicted by the coronagraph or with a much more complicated device known technically as spetroheliokinematograph.—That's a word for you.—One of these instruments is located not far from Pontiac, Michigan, at the McMath-Hulbert Observatory of the University of Michigan, a very important tool indeed in the modern attack on solar problems. The first motion pictures of solar eruptions came from the McMath-Hulbert Observatory.

But for observations of the corona, only the coronagraph has had success. Experiments employing television technique to eliminate some of the sky glare are under way at the McDonald Observatory in Texas. Thus, we hope eventually to be able to solve the problems of the corona.

We know that the form of the corona varies from year to year, probably from day to day, and not unlikely even from minute to minute. But the outstanding characteristic of its changes are over the eleven-year cycle of the sun-spot period. Dr. Goldberg spoke of this two weeks ago, and you are doubtless familiar with the broad aspects of the subject. Let me remind you that the number of spots seen on the sun, when recorded from year to year, shows a marked progressive change. At first there may be a rise in the number. A maximum is reached, and then the number declines until perhaps the sun, at times, may be quite spotless. And then the number increases until another maximum is reached. At present we are just past one of the maxima. Spots are still quite active, however.

Now, when there are lots of spots, the long, hairy streamers of the corona present a sort of wind-blown effect, stretching in almost every direction. But at sun-spot minimum, the sun's corona appears to have been carefully combed with a part around the poles, and the hairy streamers stretching outward from the equator. We do not know why this variation occurs, but it may be associated in some way or other with the magnetic fields possessed by spots and by the sun itself. This is one of the problems that we shall be able to investigate more fully with the coronagraph. More day-to-day records will show how streamers tend to arrange themselves with respect to the spots. And this information can tell us a great deal.

Although the coronagraph will undoubtedly contribute a great deal toward our knowledge of the sun itself, we may reasonably expect it

to help us in interpreting the effects of the sun and solar variation on the earth. The problems of magnetic storms, radio interference, and even such questions as the influence of solar variation on the weather, will all come into account. It is clear that some effect of this sort might be expected, but much work is required before we shall be able to understand what connection, if any, exists between the solar variability and weather phenomena.

Much has been written about the effects of solar radiation on the earth; it has been argued that sun-spots may affect living things, and that they may even have an effect on economic conditions. Statements regarding such effects are, at least at present, mostly speculation, and have little foundation as far as the facts of observation are concerned. Certainly we need more observational data to work with.

For the astronomer, however, the greatest immediate interest in the coronagraph is the hope that it will solve many of the present outstanding problems of the nature of this mysterious aura. In addition to its motions and changes, we should like to know of what sort of material it is composed. As Dr. Boyce told you last week, we have been unable to match any of the coronal radiations with radiations from known substances here on earth. We are quite sure that "coronium", which is what astronomers term the substance or substances, for want of a better name, is not a new chemical element, but merely some well-known material in disguise. Under the peculiar conditions that exist in the solar corona, the unusual radiations are emitted. The coronagraph will permit further study of the spectrum without the long wait between eclipses. Further, particularly in the infra-red range, long exposures are possible which could not be made during the short time of totality. Thus, we expect the coronagraph to contribute to our understanding of what is going on around the sun.

I hope that my assistant, Mr. Walter Roberts, and Mrs. Roberts are listening to this program from the coronagraph station at Climax. If they are, and if the sun is still courteous enough to permit reception, I should like to convey to them and to my many other friends at Climax a word of appreciation for the part they have played in getting this instrument working. At last report, there were two or three feet of snow at Climax. That is by no means unusual, for the annual fall there is about twenty feet. Even so, the roads are kept open all winter, and we have a decided advantage over Lyot, in that we can drive to the Observatory door, whereas Lyot's observations are confined to about two months in the warmest part of the summer. Climax, at best, is a rather cool spot. I experienced a severe blizzard there last July 26, and it is likely to snow almost any month of the year. I appreciated the remark made by one of the miners when he said, "I missed summer this year. I was on night shift that week." "You didn't miss much," comforted a second miner, "It snowed both days."

Science must go on, whatever be the hardships and difficulties. For

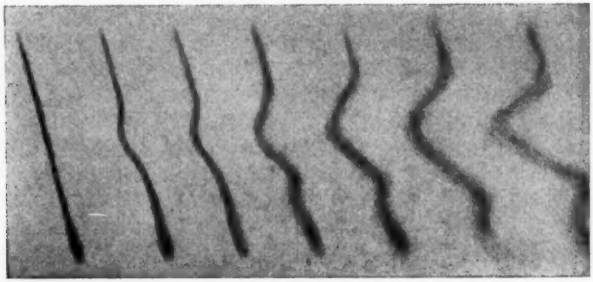
scientists are like pioneers. They are explorers plunging into the wilderness of human ignorance, exploring the unfamiliar paths of nature. No one can predict where the studies lead us, except that it must be to a higher plane. Our present-day radio came from an electric spark and a mathematical equation. Our modern engineering is founded on the mathematical procedure invented to calculate the orbits of the planets. And we can never tell what may eventually come from study of the sun. We know only that solar research is extremely important—perhaps one of the most important subjects in the world. For we owe everything to the sun: light, power, heat, vegetation, and even our very existence. It is small wonder, indeed, that primitive peoples have so universally acclaimed the sun as a god.

HARVARD OBSERVATORY, DECEMBER, 1940.

A Peculiar Fireball on June 21, 1937*

By MASAAKI HURUHATA

On the evening of June 21, 1937, before the sky was completely dark, a peculiar fireball that left a very remarkable train was observed by the writer in Tokyo. Fortunately the fireball was seen by several people from various places other than Tokyo; hence the writer was able to verify certain of the peculiarities he had observed.



0^m1 0^m5 1^m0 1^m5 2^m5 3^m0

CHANGE OF THE TRAIN

According to observations from Yusima, Hongo, Tokyo, the meteor appeared at $19^h\,44^m.3$, Japanese Standard Time. Its brightness was -6^M; its color was blue at first, then changed to red; the duration was $1^s.0$. The positions of the appearance and disappearance were somewhat uncertain, because only bright stars were visible at that time, but positions were determined with respect to trees and houses as well as stars. After traveling eight-tenths of its entire path the fireball became quite

*Condensed from *Astronomical Herald*, Vol. 31, No. 11, 1938.

faint, then flared up in a final reddish burst. The most interesting part of the fireball's appearance was the very beautiful train, resembling white smoke, that was left along the entire trail. The central part of the train gradually began to shift in a westerly direction, until, spreading slowly, the train itself had completely disappeared after about four minutes. The sketch shows the changes as seen from the writer's location.

The same remarkable changes were reported by two or three amateur astronomers in Tokyo. A few detailed reports came from Niigata City, a hundred and fifty miles northwest of Tokyo, including observations of position, color, duration, and the remarkable train. In Nagano-prefecture, which lies between Tokyo and Niigata, some ten people reported observations with descriptions of the train, but none of them noticed its subsequent changes in shape.

To determine the real path of this fireball, the writer used mainly the following values derived from the above reports.

(a) At Hongo, Tokyo:

	Direction	Altitude
Appearance	N 2° W	28°
Disappearance	N 4 E	14

(b) At Niigata:

	R.A.	Decl.
Appearance	233°	—18°
Disappearance	260	—25

The real path of the fireball was determined as follows:

	L	ϕ	Height
Beginning	139°.7 E	36°.9 N	77 km
Ending	139.9	37.2	43

The length of the trail was thus 53 km, and the radiant point was at R.A. = 185°, Decl. = —2°, near μ Virginis.

The duration of $1^s.0$, estimated by the writer, indicates a speed of 53 km per second, but this value is not reliable. The height of the beginning seems too low, probably because the remaining daylight rendered the first part undetectable.

It is remarkable that the spectacular change of the train as observed in Tokyo was less apparent at Niigata, and was not noticed at all in Nagano-prefecture. These results leave no doubt that the movement of the central part of the train was toward the west-northwest. The writer's estimate of motion, 3° in 3.5 minutes, gives a real distance of 12 km in the same interval of time, or 127 miles per hour. The real height of the central part was 65 km; the part of the train where appreciable motion was observed was between heights of 55 km to 70 km. Besides this movement, motion to a lesser extent was observed in the lower part of the trail, but its real direction was uncertain. In spite of such distortions, some parts of the train seemed to be standing still, in particular at altitudes above 70 km, around 55 km, and below 45 km.

Harvard College Observatory.

Mersenius Clefts R1, R2, R3, R4

By ROBERT BARKER

Lunar observational research today has attained a high standard of advancement due to the interested patient work of amateurs equipped with telescopes of high optical excellence. Although 9 inches would appear to be the smallest aperture for really serious work, it can be generally regarded that any aperture over 12 inches is of no advantage, unless the observer is very favorably situated in an area where clear skies and steady definition prevail.

With a suitable telescope, a copy of Goodacre's "Moon", and a good nodding acquaintance with lunar features, especially the finer clefts, it is surprising how the student, who possesses these qualifications, can sometimes light upon some feature that seems to differ very markedly from the mapped records of Goodacre, Neison, Wilkins, and Schmidt. Here is a case in point.

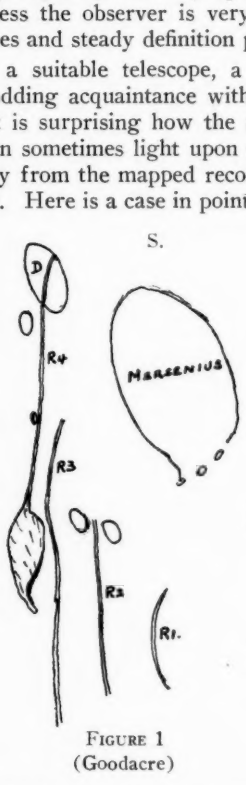


FIGURE 1
(Goodacre)

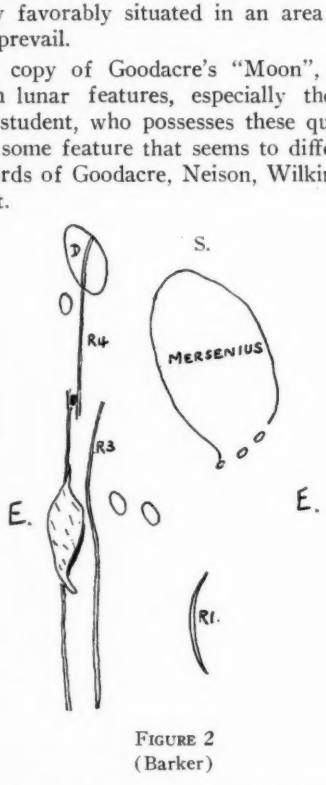


FIGURE 2
(Barker)

On 1940 March 20, I was examining Goodacre's Section XX chart before going to my 12.6-inch Calver reflector. The area west of Mersenius was then very favorably placed near terminator. I was paying particular attention to some well-marked parallel clefts in this district, running S to N between Mersenius and Gassendi, marked by Goodacre R4, R3, R2, and R1.

Goodacre showed R4 unbroken in its course, ending N at a rocky plateau, and I curiously noted that a fine drawing of Mersenius by Durrad, 10 pages later, gave a break in R4, and a short parallel cleft which took up the running, ending N at the rocky plateau. With this disagreement by skilled observers and draughtsmen in mind, I searched keenly this debatable area, with a Dall eyepiece × 360.

The seeing was excellent, the program inviting, and interesting results were secured. R4 showed two short parallel clefts closely resembling Durrad's drawing, the westernmost cleft ending N at a rocky plateau. Then I saw that N of this tableland a cleft continued far N running parallel to R3. The cleft R2 apparently did not exist, though the difficult, shorter cleft R1 (slightly concave to E) was in evidence.

Figure 1 gives Goodacre's record and Figure 2 my own; these diagrams, though rough, are drawn to scale.

The matter is interesting, for it seems to prove that even such a devoted, lifelong student of the Moon as Goodacre can be caught napping, as he never seemed to notice, and investigate, the difference that existed between his chart and Durrad's drawing. Figure 2 is necessarily incomplete in fine detail, and many delicate features are yet to be made before this new presentation of these clefts is complete; a task I would have finished myself had not war circumstances prevented me.

I cannot at present use my Calver at night, though darkness and "blackout" give very clear, dark skies. Raiding planes are then frequently passing, and though I do not fear them as much as the falling shell fragments from our very effective gun barrage, I am forced to take cover against the latter danger. So I endeavor to possess my soul in patience "until this tyranny be overpast," with the hope that my American cousins may take interest in this rather fascinating lunar problem I have set forth.

The magnificent walled plain Gassendi will be seen a little W. The uneven interior floor is marked with the most delicate and intricate system of branching clefts to be found on the lunar surface. A complete, accurate chart, confirmed by several first class observers, of these most difficult clefts, has yet to be made.

CHESHUNT, HERTS, ENGLAND.

Group Meeting of Midwest Astronomers

By JESSE L. GREENSTEIN

At the invitation of Dr. O. J. Lee, the second meeting of astronomers of the Midwest Group was held at the Dearborn Observatory, March 22. The general subject of the papers was "Banded Stellar Spectra". Dr. Lee reviewed the aim, methods, and progress of the extensive Dearborn survey of the spectra of stars of types K and later. The first volume of spectral types and magnitudes of red stars to $11^{M}.5$ will soon

appear. The classification has revealed many new stars of the rare R, N, and S types. Dr. Baldwin, of the Dearborn Observatory, described various peculiar spectra that have been discovered by the Dearborn observers. Some stars show unexpected variations of the relative intensity of certain of the molecular bands, when compared with normal stars of the same spectral type; variations in the intensity distribution also occur. After the conclusion of the meeting, Dr. Lee had arranged a display of the original plates used in the investigation, for examination by the visiting astronomers, with many of the peculiar objects marked.

Mrs. Cecilia Payne Gaposchkin discussed the recent Milton Bureau investigation of the interesting Cepheid-like variable, RU Cam, a star which develops R type bands at minimum. The period, about 22 days, varies in a 3000 day cycle, so that the maximum may occur as much as four days later than that predicted with a constant period. On correction for the variation of period, the star has a constant light curve.

Dr. W. W. Morgan, in collaboration with Dr. P. Keenan, described the progress made at the Yerkes Observatory in the classification of the R and N stars by means of their line spectra. Suitable line ratios are being found to arrange the stars in a temperature sequence. A discussion of the variation of the band intensities with respect to this classification shows that CN has a flat maximum. The double maximum for the C_2 bands, found in the conventional classification, disappears. There is some evidence for a slight maximum of C_2 on the new classification, but there is a wide variation of the C_2 bands within a given spectral class. Apparently, the abundance of carbon varies from star to star among the "carbon stars".

The next meeting of this group will be held at the Washburn Observatory about the middle of May.

Planet Notes for May, 1941

By R. S. ZUG

NOTE: Greenwich Civil Time is employed unless otherwise stated. To obtain Eastern Standard Time subtract 5 hours, Central Standard Time, 6 hours, etc. The planetary phenomena are described as they are to be seen from latitude 45° N. The data are taken chiefly from the *American Ephemeris and Nautical Almanac*.

Sun. The sun will be moving through the constellation Aries during the first part of May, thence through the constellation Taurus.

Moon. Phenomena of the moon will occur as follows:

		h	m
First Quarter	May 4	12	49
Full Moon	11	5	15
Last Quarter	18	1	17
New Moon	26	5	18
Perigee	May 10	19	
Apogee	23	18	

An Unusual Series of Planetary Conjunctions. The first part of May finds five planets, Mercury, Venus, Saturn, Jupiter, and Uranus located but a few degrees east of the sun, the situation resulting in an interesting series of planetary conjunctions as tabulated below. Further information is given on pages 27-28, of POPULAR ASTRONOMY for January, 1941.

PLANETARY CONJUNCTIONS IN MAY, 1941

G.C.T.	Conjunction between	Angular separation	Planet to the North	Elongation from Sun
May 4 18^h	Venus and Saturn	1° 33′	Venus	5° E
7 7	Jupiter and Uranus	0 32	Uranus	10 E
7 17	Mercury and Saturn	2 19	Mercury	2 E
11 4	Venus and Uranus	0 5	Uranus	6 E
11 5	Mercury and Uranus	1 3	Mercury	6 E
11 6	Mercury and Venus	1 8	Mercury	6 E
11 13	Mercury and Jupiter	1 38	Mercury	6 E
11 20	Venus and Jupiter	0 28	Venus	6 E

Mercury. Mercury reaches superior conjunction on May 6, and by the end of May should be quite conspicuous in the evening sky.

Venus. Venus will have passed superior conjunction, and on May 1 may be found in the evening sky, close to the sun. By the end of the month it should be easily located in the early evening sky.

Mars. Mars is nearing western quadrature (quadrature on June 2). On May 1 the planet will be 112,239,000 miles distant from the earth, 7″.7 in angular diameter, and of stellar magnitude + 0.9. The corresponding data for June 1, are, respectively, 91,722,000 miles, 9″.5, and + 0^M.1. During May the planet will be moving eastward through Capricornus and Aquarius, and will rise about midnight. Information enabling observers to identify the Martian longitude of the center of the planetary disk and the surface markings visible at any time may be found on pages 30-32 of POPULAR ASTRONOMY for January, 1941.

Jupiter. Jupiter reaches conjunction on May 19. Consecutive conjunctions with Uranus, Mercury, and Venus will occur during May as explained above.

Saturn. Saturn reaches conjunction on May 9. Conjunctions with Venus and Mercury are described above.

Uranus. Uranus reaches conjunction on May 17.

Neptune. Neptune is in the constellation Virgo, and may be located telescopically with the aid of the chart which appeared on page 35 of the January, 1941, issue of POPULAR ASTRONOMY. Examination of the chart reveals that on May 1 the planet in its apparent motion will pass close to a faint B.D. star.

Occultation Predictions

(Taken from the *American Ephemeris*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phe-

nomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′

Date 1941	Star	Mag.	IMMERSION Greenwich C.T.	IMMERSION *a*	IMMERSION *b*	IMMERSION Angle E from N	EMERSION Greenwich C.T.	EMERSION *a*	EMERSION *b*	EMERSION Angle E from N
			h m	m	m	°	h m	m	m	°
May 14	BD—19.5047	6.9	7 53.5	—2.0	—0.5	110	9 5.6	—1.6	+0.1	241
16	31 B. Cap	6.4	8 25.8	—2.1	—0.2	117	9 27.3	—1.5	+1.6	213

OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′

May 14	95 B. Sgr	5.8	6 49.5	..	..	13	7 4.5	..	..	350
14	BD—19°5047	6.9	7 20.5	—1.6	0.0	118	8 30.5	—2.0	+1.0	241
16	31 B. Cap	6.4	7 54.7	—1.3	+0.2	122	8 52.3	—1.7	+2.2	217
29	26 Gem	5.1	2 37.6	—0.2	—0.3	56	3 17.8	+0.7	—2.2	321
31	29 Cnc	5.9	3 32.3	—0.2	—1.2	90	4 26.6	+0.3	—1.7	301

OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′

May 5	*o* Leo	3.8	6 52.0	—0.8	—1.2	95	7 52.9	—0.2	—2.0	306
14	95 B. Sgr	5.8	5 53.7	—0.6	+1.7	71	6 50.4	—0.5	+0.3	298
14	BD—19°5047	6.9	7 2.9	..	..	168	7 21.7	..	..	201
18	150 B. Aqr	6.1	10 10.8	—0.8	+0.9	105	11 12.9	—1.2	+2.4	221
31	29 Cnc	5.9	3 26.3	—0.7	—2.1	127	4 30.4	—0.6	—1.3	270

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

One of the most useful types of work that can be done by A.M.S. groups is to plan simultaneous observations from two or more stations. Last August this was done by three groups of the Amateur Astronomers of the Franklin Institute, working with other nearby groups. For most of these observers this was their first attempt at plotting meteors. The results were printed in these Notes. One of their most active members, Mr. Roland Shutts, planned with me to carry out a second attempt in October, while the Orionid meteors were visible. The first night selected was cloudy but the second, that of October 26-27, 1940, was favorable, and three stations were occupied. These were: No. 1, λ 75° 15′ W, φ 40° 04′ N; manned by A. Eichelberger, W. Fahy, and R. Shutts; No. 2, λ 74° 47′ W, φ 40° 10′ N, manned by E. Klein, A. Busedu, R. Gorson, and D. McKannan; No. 3, λ 75° 08′ W, φ 40° 25′ N, manned by J. Connors and T. Schatchard. The coördinates of these stations are not known more exactly than given, as the stations had to be plotted on road maps and then transferred to standard maps for measurement. At No. 1 from 11:50 to 13:50 E.S.T., 30 meteors, at No. 2 from 11:15 to 14:45 E.S.T., 61 meteors, and at No. 3, from 12:00 to 14:00 E.S.T., 32 meteors were observed. All stations had good skies and the moon was absent. All the meteors seen were fully entered on the record sheets and nearly all were also plotted on maps.

I handed over these observations to Miss Edith Reilly, one of our graduate students majoring in Astronomy, who kindly volunteered to reduce them. This she has done fully, I only acting as adviser and doing a little checking here and there. I wish to express sincere thanks to her for her excellent and accurate

work. The three stations formed nearly an equilateral triangle, the sides being about 35 km. This is of course rather short and 60 to 80 km would have been preferable. But it was not practicable for the observers to go so far from Philadelphia. When the observations were reduced the usual causes functioned to make it possible to use only a small percentage for heights. These were: first, that the observers evidently were not always looking where coincidences would have occurred; second, that for most of them this was only their second attempt at plotting meteors; third, that wrist watches were used by several with attendant probable misreading of the whole minutes (due to faint light) and probable lack of synchronization of minute and second hands on some of the watches; and, lastly, that most of the meteors were not particularly conspicuous. However, the groups are enthusiastic and on a third attempt most of these troubles can be ironed out. When all possible coincidences, based upon agreement in time, were worked up, five heights were computed. Two of these proved impossibly low; in each case obviously *not* the same meteor had been seen at both stations, despite approximate time agreement. For three I find the following results:

Average E.S.T.						
h	m	s	Magn.	Sta. 1	Sta. 2	Sta. 3
12	17	28	1,—	7	—	4
12	44	26	4,—	11	—	10
13	58	56	1,1,—	30	52	32

	Beginning	End
The respective heights were:	100.3 ± 1.7 km	67.8 ± 11.3 km
	96.9 ± 2.7	69.5 ± 4.5
	67.7 ± 9.0	44.0 ± 3.1

These results I consider very good for this type of work and very promising for future efforts by the same observers. It does seem strange that no Orionid is included among the three because over half of the meteors seen belonged to that stream. I have not worked up the radiants for I think such radiants have little value until the observers become skilled. This remark applies to both the three individual cases given and the maps as a whole. That so few coincidences were secured proved what a large number of meteors per hour was really visible and what an enormous percent any one observer perforce misses. Ideally, there should be two observers at each station both looking in the same direction and plotting alternately so that, in the long run, one of them will always be watching the sky. This precaution would probably quadruple the number of meteors available for height computation and is recommended where the requisite number of plotters is available.

Since our annual report appeared in the March Meteor Notes, one misplaced report of Loreta and two other short ones have become available, so the following should be added to the 1940 totals.

Horton, W. P.	15 meteors	
Wallace, Wm.	8	
Loreta	362	53 plotted, others described.
Fireballs	2	
Total	387	

The two spring showers will come at favorable times as to moonlight and it is hoped all our members will make an attempt to observe both the Lyrids and Eta Aquarids. The first are generally at maximum on or about April 21 and the lat-

ter from May 2 to 6 with no particular day especially outstanding. The Aquarids are especially important due to their connection with Halley's Comet. Therefore, I would greatly appreciate a real effort to get good results on them. Last year in Florida they furnished a really fine display on the nights of May 3 and 4.

Mail addressed to the following members has been returned unclaimed: Stuart O'Bryne, G. H. Fentress, and C. H. Travis. If anyone knows their present addresses please let us have them. Bills for the annual dues were sent out recently; will our members, who are still delinquent, please attend to the matter.

Flower Observatory,
Upper Darby, Pa., 1941 March 13

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD,
Department of Astronomy, University of California, Los Angeles

President of the Society: H. H. NININGER, Colorado Museum of Natural History and American Meteorite Laboratory, Denver

Secretary of the Society: ROBERT W. WEBB, Department of Geology, University of California, Los Angeles

Statistical Studies of the Meteoritic Falls of the World: 2. Their Areal Concentration

By FREDERICK C. LEONARD *with* BORIS SLANIN

ABSTRACT

This paper is a continuation of the related article in *C.S.R.M.* for March, 1941. It consists mainly of 3 tables exhibiting the areal concentration of the meteoritic falls of (1) the United States, (2) countries other than the United States, and (3) the continents and the world (1388 falls in all) and a short discussion of the material in each table. Many of the conclusions reached in the present study are in striking contrast to, though they are of course quite in harmony with, those set forth in the earlier paper. *Density of population* is seen clearly to be a reason for the *concentration* of known meteoritic falls, while a sixteenth point favoring the recovery of meteorites is recognized and stated.

This paper is a continuation of that entitled, "A Statistical Study of the Meteoritic Falls of the World as of Date 1941 January 1"[1]; like its predecessor, it consists essentially of 3 tables. Table 1 contains the data for the meteoritic falls of the United States. The first column gives the name of the State (and of the United States); the second, its area in *tens of thousands* of square miles ($a/10^4$); the third and fourth, the number (n) of the aërolitic falls (A.) in the area and the number of such falls per ten thousand square miles ($c = 10^4 n/a$, which shall be called the *concentration-index*), respectively; the fifth and sixth, the same kind of information for the siderolitic falls (So.); the seventh and eighth, that for the sideritic falls (Si.); the ninth and tenth, that for the total number of observed falls (O); the eleventh and twelfth, that for the total number of unobserved falls (U); the thirteenth and fourteenth, that for the grand total number (T) of both O and U falls; and the fifteenth, a quantity $d = 10^2/\sqrt{c}$ (c

being the concentration-index listed in the immediately preceding—the fourteenth —column), expressed to the nearest mile. The last line of the table contains the statistics for the entire United States. Evidently c, from its definition, is a direct measure of the *concentration* of the falls in the area to which it pertains, while d would be the *least* distance, in miles, between *adjacent* falls, if they were distributed *uniformly* (*not* at random) within the area.

We see from Table 1, for the United States, that—

(1) The 7 States having the highest concentration of A. falls are Kansas (5.50^2), Colorado (2.22), Nebraska (2.21), Connecticut (2.07), Maryland (2.01), Texas (1.91), and North Carolina (1.85).

(2) The 3 States having the highest concentration of So. falls are Kentucky (0.498), Ohio (0.491), and Tennessee (0.480).

(3) The 6 States having the highest concentration of Si. falls are North Carolina (3.90), Tennessee (3.60), Kentucky (3.48), Georgia (2.21), Connecticut (2.07), and Maryland (2.01).

(4) The 5 States having the highest concentration of *O* falls (all 3 kinds) are Connecticut (4.15), Maryland (2.01), North Carolina (1.64), Maine (1.34), and New Jersey (1.33).

(5) The 7 States having the highest concentration of *U* falls are Kansas (5.50), North Carolina (4.10), Kentucky (3.98), Tennessee (3.84), Colorado (3.57), Nebraska (2.86), and Texas (2.82).

(6) The 7 States having the highest concentration of all 3 kinds of falls (both *O* and *U*) combined are Kansas (6.11, 40^2), North Carolina (5.74, 42), Kentucky (4.73, 46), Tennessee (4.56, 47), Connecticut (4.15, 49), Maryland (4.02, 50), and Colorado (3.76, 52). *Cf.* the foregoing figures with the data for the whole United States, for which, *e.g.*, the final $c = 1.68$ and $d = 77$.[4]

The arrangement of Table 2, for countries other than the United States, and of Table 3, for the continents and the world, is precisely like that of Table 1. Referring now to Table 2, we note that—

(1) The 6 countries having the highest concentration of A. falls are Switzerland (3.14), France (2.59), Czechoslovakia (2.58), Belgium (2.55), Holland (2.38), and Lithuania (2.33). *Cf.* the U.S. with 0.824.

(2) The 3 countries having the highest concentration of So. falls are Chile (0.175), Germany (0.166), and Spain (0.103). *Cf.* the U.S. with 0.0673.

(3) The 6 countries having the highest concentration of Si. falls are Czechoslovakia (1.66), Chile (1.12), Switzerland (0.627), Japan (0.610), Mexico (0.592), and Estonia (0.545). *Cf.* the U.S. with 0.787.

(4) The 6 countries having the highest concentration of *O* falls (all 3 types) are Switzerland (3.14), Czechoslovakia (2.77), Belgium (2.55), France (2.49), Holland (2.38), and Lithuania (2.33). *Cf.* the U. S. with 0.313.

(5) The 5 countries having the highest concentration of *U* falls are Czechoslovakia (1.48), Chile (1.47), Switzerland (0.627), Germany (0.608), and Mexico (0.592). *Cf.* the U.S. with 1.37.

TABLE 1

THE AREAL CONCENTRATION OF THE METEORITIC FALLS OF THE U. S.[1]

		— A. —		— So. —		— Si. —		— O —		— U —		TOTAL — T —		
STATE	$a/10^4$	n	c	n	c	n	c	n	c	n	c	n	c	d
ALABAMA	5.13	6	1.17	—	—	6	1.17	5	0.975	7	1.37	12	2.34	65
ARIZONA	11.38	3	0.264	1	0.0879	14	1.23	1	0.0879	17	1.49	18	1.58	80
ARKANSAS	5.25	3	0.571	1	0.190	4	0.762	5	0.952	3	0.571	8	1.52	81
CALIFORNIA	15.57	4	0.257	—	—	7	0.450	—	—	11	0.707	11	0.707	119
COLORADO	10.37	23	2.22	2	0.193	14	1.35	2	0.193	37	3.57	39	3.76	52
CONNECTICUT	0.48	1	2.07	—	—	1	2.07	2	4.15	—	—	2	4.15	49
FLORIDA	5.49	2	0.365	—	—	—	—	—	—	2	0.365	2	0.365	166
GEORGIA	5.87	4	0.681	—	—	13	2.21	4	0.681	13	2.21	17	2.89	59
IDAHO	8.34	—	—	—	—	2	0.240	—	—	2	0.240	2	0.240	204
ILLINOIS	5.60	2	0.357	—	—	—	—	2	0.357	—	—	2	0.357	167
INDIANA	3.60	5	1.39	1	0.277	4	1.11	2	0.555	8	2.22	10	2.77	60
IOWA	5.56	3	0.540	1	0.180	1	0.180	4	0.720	1	0.180	5	0.900	105
KANSAS	8.18	45	5.50	3	0.367	2	0.245	5	0.611	45	5.50	50	6.11	40
KENTUCKY	4.02	3	0.747	2	0.498	14	3.48	3	0.747	16	3.98	19	4.73	46
LOUISIANA	4.54	1	0.220	—	—	—	—	—	—	1	0.220	1	0.220	213
MAINE	2.99	4	1.34	—	—	—	—	4	1.34	—	—	4	1.34	86
MARYLAND	0.99	2	2.01	—	—	2	2.01	2	2.01	2	2.01	4	4.02	50
MICHIGAN	5.75	2	0.348	—	—	3	0.522	2	0.348	3	0.522	5	0.870	107
MINNESOTA	8.09	2	0.247	—	—	1	0.124	1	0.124	2	0.247	3	0.371	164
MISSISSIPPI	4.64	2	0.431	—	—	1	0.216	2	0.431	1	0.216	3	0.647	124
MISSOURI	6.87	7	1.02	1	0.146	7	1.02	5	0.728	10	1.46	15	2.18	68
MONTANA	14.61	—	—	—	—	1	0.0684	—	—	1	0.0684	1	0.0684	382
NEBRASKA	7.68	17	2.21	—	—	8	1.04	3	0.391	22	2.86	25	3.25	55
NEVADA	10.98	—	—	—	—	2	1.82	—	—	2	0.182	2	0.182	234
NEW JERSEY	0.75	1	1.33	—	—	—	—	1	1.33	—	—	1	1.33	87

TABLE 1—(CONTINUED)

State	$a/10^4$	A.		So.		Si.		Total O		Total U		Total T	
		n	c	n	c	n	c						
New Mexico	12.25	15	1.22	1	0.0816	15	1.22	2	0.163	29	2.37	31	2.53	63
New York	4.77	3	0.630	—	—	4	0.839	1	0.210	6	1.26	7	1.47	82
North Carolina	4.87	9	1.85	—	—	19	3.90	8	1.64	20	4.10	28	5.74	42
North Dakota	7.02	1	0.142	—	—	3	0.427	1	0.142	3	0.427	4	0.570	132
Ohio	4.07	2	0.491	2	0.491	3	0.736	2	0.491	5	1.23	7	1.72	76
Oklahoma	6.94	4	0.576	—	—	4	0.576	2	0.288	6	0.864	8	1.15	93
Oregon	9.56	—	—	1	0.104	2	0.209	—	—	3	0.314	3	0.314	178
Pennsylvania	4.48	1	0.223	—	—	5	1.12	1	0.223	5	1.12	6	1.34	86
South Carolina	3.05	3	0.984	—	—	4	1.31	3	0.984	4	1.31	7	2.30	66
South Dakota	7.69	1	0.130	—	—	2	0.260	1	0.130	2	0.260	3	0.390	160
Tennessee	4.17	2	0.480	2	0.480	15	3.60	3	0.720	16	3.84	19	4.56	47
Texas	26.24	50	1.91	1	0.0381	29	1.11	6	0.229	74	2.82	80	3.05	57
Utah	8.22	1	0.122	—	—	4	0.487	—	—	5	0.608	5	0.608	128
Virginia	4.03	3	0.745	—	—	7	1.74	4	0.993	6	1.49	10	2.48	64
Washington	6.68	1	0.150	—	—	1	0.150	1	0.150	1	0.150	2	0.299	183
West Virginia	2.40	—	—	—	—	2	0.833	—	—	2	0.833	2	0.833	110
Wisconsin	5.53	3	0.543	—	—	4	0.724	3	0.543	4	0.724	7	1.27	89
Wyoming	9.75	4	0.410	1	0.103	4	0.410	—	—	9	0.923	9	0.923	104
U.S.	297.37	245	0.824	20	0.0673	234	0.787	93	0.313	406	1.37	499	1.68	77

NOTE TO TABLE 1

[1]All the data in the column headed $a/10^4$ have been "rounded off," in Tables 1 and 2, to the nearest *hundred* square miles, and in Table 3, to the nearest *ten thousand* square miles. In making the calculations for the tables, however, the values of the areas as listed in Hammond's *Modern Illustrated Atlas of the World*, 1937-38, have been employed. The values of the c's in all 3 tables have been computed to *3 significant figures.*

TABLE 2

THE AREAL CONCENTRATION OF THE METEORITIC FALLS OF COUNTRIES OTHER THAN THE U. S.

COUNTRY	$a/10^4$	— A. —		— So. —		— Si. —		TOTAL — O —		— U —		— T —		
		n	c	n	c	n	c	n	c	n	c	n	c	d
AFRICA (MISC.)[1]	360.09	12	0.0333	1	0.00278	3	0.00833	12	0.0333	4	0.0111	16	0.0444	474
ALGERIA	84.76	4	0.0472	—	—	3	0.0354	3	0.0354	4	0.0472	7	0.0826	348
ARABIA	100.00	4	0.0400	—	—	3	0.0300	1	0.0100	6	0.0600	7	0.0700	378
ARGENTINA	108.00	10	0.0926	2	0.0185	3	0.0278	5	0.0463	10	0.0926	15	0.139	268
ASIA (MISC.)[2]	202.04	7	0.0346	1	0.00495	1	0.00495	8	0.0396	1	0.00495	9	0.0445	474
AUSTRALIA[3]	297.46	25	0.0840	8	0.0269	54	0.181	5	0.0168	82	0.276	87	0.292	185
AUSTRIA	3.24	4	1.24	—	—	—	—	3	0.927	1	0.309	4	1.24	90
BELGIUM	1.18	3	2.55	—	—	—	—	3	2.55	—	—	3	2.55	63
BOLIVIA	51.42	—	—	1	0.0194	2	0.0389	—	—	3	0.0583	3	0.0583	414
BRAZIL	328.62	9	0.0274	—	—	7	0.0213	8	0.0243	8	0.0243	16	0.0487	453
BRITISH ISLES	12.09	16	1.32	—	—	2	0.165	16	1.32	2	0.165	18	1.49	82
ENGLAND & WALES	5.83	7	1.20	—	—	1	0.171	8	1.37	—	—	8	1.37	85
IRELAND	3.18	5	1.57	—	—	1	0.314	5	1.57	1	0.314	6	1.88	73
SCOTLAND	3.04	4	1.32	—	—	—	—	3	0.987	1	0.329	4	1.32	87
CANADA	345.75	6	0.0174	1	0.00289	12	0.0347	4	0.0116	15	0.0434	19	0.0549	427
CENTRAL AMER. (MISC.)[4]	11.17	1	0.0895	—	—	2	0.179	1	0.0895	2	0.179	3	0.269	193
CHILE	28.64	5	0.175	5	0.175	32	1.12	—	—	42	1.47	42	1.47	83
CHINA	430.00	3	0.00698	1	0.00232	—	—	4	0.00930	—	—	4	0.00930	1037
CZECHOSLOVAKIA	5.42	14	2.58	—	—	9	1.66	15	2.77	8	1.48	23	4.24	48
ESTONIA	1.84	2	1.09	—	—	1	0.545	2	1.09	1	0.545	3	1.63	78
EUROPE (MISC.)[5]	10.86	4	0.368	—	—	1	0.0921	5	0.460	—	—	5	0.460	147
FINLAND	13.26	6	0.453	1	0.0754	—	—	5	0.377	2	0.151	7	0.528	138
FRANCE[6]	21.27	55	2.59	—	—	1	0.0470	53	2.49	3	0.141	56	2.63	62
FRENCH INDO-CHINA	28.50	4	0.140	—	—	—	—	4	0.140	—	—	4	0.140	267
FRENCH W. AFRICA	160.42	4	0.0249	—	—	3	0.0187	5	0.0312	2	0.0125	7	0.0436	479
GERMANY	18.10	23	1.27	3	0.166	8	0.442	23	1.27	11	0.608	34	1.88	73
HOLLAND	1.26	3	2.38	—	—	—	—	3	2.38	—	—	3	2.38	65
HUNGARY	3.59	5	1.39	—	—	1	0.279	5	1.39	1	0.279	6	1.68	77
INDIA	181.90	104	0.572	3	0.0165	4	0.0220	108	0.594	3	0.0165	111	0.610	128
ITALIAN SOMALILAND	19.40	2	0.103	—	—	1	0.0515	2	0.103	1	0.0515	3	0.155	254
ITALY	11.98	17	1.42	—	—	1	0.0835	18	1.50	—	—	18	1.50	82
JAPAN	14.76	25	1.69	—	—	9	0.610	26	1.76	8	0.542	34	2.30	66
JAVA	5.12	6	1.17	—	—	2	0.390	7	1.37	1	0.195	8	1.56	80
KOREA (CHOSEN)	8.52	2	0.235	—	—	—	—	2	0.235	—	—	2	0.235	206
LATVIA	2.54	5	1.97	—	—	—	—	5	1.97	—	—	5	1.97	71
LITHUANIA	2.15	5	2.33	—	—	—	—	5	2.33	—	—	5	2.33	66

TABLE 2—(CONTINUED)

COUNTRY	$a/10^4$	TOTAL — O —		— U —		— T —		
		n	c	n	c	n	c	d
MEXICO	65.00	2	0.0154	1	0.00769	3	0.0231	1040
NETHERLANDS	1.26	3	2.38	—	—	3	2.38	65
NEW ZEALAND	26.82	2	0.0746	1	0.0373	3	0.112	1040
NORWAY	32.38	1	0.0309	—	—	1	0.0309	1040
PERSIA	165.00	1	0.00606	—	—	1	0.00606	1040
PERU	128.00	1	0.00781	—	—	1	0.00781	1040
PHILIPPINE ISLANDS	30.00	1	0.0333	—	—	1	0.0333	1040
PORTUGAL	8.92	1	0.112	—	—	1	0.112	1040
RUSSIA[7]	1707.00	1	0.00059	—	—	1	0.00059	1040
SPAIN	50.00	1	0.0200	—	—	1	0.0200	1040
SWEDEN	44.98	1	0.0222	—	—	1	0.0222	1040
SWITZERLAND	4.12	1	0.243	—	—	1	0.243	1040
TURKEY	78.00	1	0.0128	—	—	1	0.0128	1040
URUGUAY	17.00	1	0.0588	—	—	1	0.0588	1040
WEST INDIES	13.00	1	0.0769	—	—	1	0.0769	1040
ZANZIBAR	10.00	1	0.100	—	—	1	0.100	1040

TABLE 2—(CONTINUED)

		— A. —		— So. —		— Si. —		TOTAL — O —		— U —		— T —	
MEXICO	76.03	9	0.118	1	0.0132	45	0.592	10	0.132	45	0.592	55	0.723	118
NEW ZEALAND	10.40	4	0.385	—	—	—	—	1	0.0961	3	0.288	4	0.385	161
N. AMER. (MISC.)[7]	148.12	1	0.00675	1	0.00675	4	0.0270	1	0.00675	5	0.0338	6	0.0405	497
NORWAY	12.46	6	0.482	1	0.0803	1	0.0803	6	0.482	2	0.161	8	0.642	125
PHILIPPINE ISLANDS	11.44	3	0.262	—	—	—	—	3	0.262	—	—	3	0.262	195
POLAND	15.00	4	0.267	1	0.0667	1	0.0667	5	0.333	1	0.0667	6	0.400	158
PORTUGAL	3.55	4	1.13	—	—	—	—	3	0.845	1	0.282	4	1.13	94
RUMANIA	11.39	7	0.615	—	—	—	—	6	0.527	1	0.0878	7	0.615	128
S. AMER. (MISC.)[8]	62.35	2	0.0321	—	—	1	0.0160	1	0.0160	2	0.0321	3	0.0481	456
S. W. AFRICA	32.24	1	0.0310	—	—	3	0.0931	1	0.0310	3	0.0931	4	0.124	284
SPAIN	19.42	22	1.13	2	0.103	4	0.206	24	1.24	4	0.206	28	1.44	83
SWEDEN	17.31	7	0.404	—	—	1	0.0578	6	0.347	2	0.116	8	0.462	147
SWITZERLAND	1.59	5	3.14	—	—	1	0.627	5	3.14	1	0.627	6	3.76	52
TURKEY	29.44	5	0.170	—	—	1	0.0340	5	0.170	1	0.0340	6	0.204	222
COUNTRY	$a/10^4$	n	c	n	c	n	c	n	c	n	c	n	c	d
UNION OF S. AFRICA	47.19	18	0.381	1	0.0212	15	0.318	17	0.360	17	0.360	34	0.720	118
U.S.S.R.	824.40	78	0.0946	5	0.00607	26	0.0315	71	0.0861	38	0.0461	109	0.132	275
RUSSIA[9]	176.90	61	0.345	2	0.0113	12	0.0678	54	0.305	21	0.119	75	0.424	154
SIBERIA[9]	647.50	17	0.0262	3	0.00463	14	0.0216	17	0.0262	17	0.0262	34	0.0525	436
YUGOSLAVIA	9.60	6	0.625	—	—	1	0.104	7	0.729	—	—	7	0.729	117
GEN. MISC.[10]	10.23	2	0.196	1	0.0978	—	—	3	0.293	—	—	3	0.293	185
ALL FORENAMED COUNTRIES	4217.47	579	0.137	40	0.00948	269	0.0638	541	0.128	347	0.0823	888	0.211	218

NOTES TO TABLE 2

[1] Includes Anglo-Egyptian Sudan, for which $a/10^4 = 100.81$; Cameroon, 20.41; Egypt, 38.30 (2) [The figure in parentheses is the total number of falls in the area, if this is greater than 1.]; Ethiopia, 34.75; Kenya, 22.51; Morocco (French), 16.22 (2); Nigeria, 37.27 (2); Nyasaland Protectorate, 3.76 (2); Rhodesia, 43.83; Tanganyika Territory, 37.41 (2); and Tunisia, 4.83.

[2] Includes Burma, 26.27 (2); Ceylon, 2.53; Iraq, 17.71 (2); Mongolia, 85.00; Persia, 62.80; and Syria (including Lebanon), 7.72 (2).

[3] Includes the State of Tasmania (3).

[4] Includes Costa Rica, 2.30; Guatemala, 4.24; and Honduras, 4.63.

[5] Includes Balearic Islands, 0.19; Bulgaria, 3.98 (2); Denmark, 1.66; and Greece, 5.03.

[6] Includes Corsica.

[7] Includes Alaska, 58.64 (2); Cuba, 4.42; Greenland, 83.97; Hawaiian Islands, 0.65; and Jamaica, 0.44.

[8] Includes Colombia, 44.75, and Paraguay, 17.60 (2).

[9] Russia includes all of European U.S.S.R.; Siberia, all of Asiatic U.S.S.R. See *Studies: 1*, Table 3, Note 2.

[10] Includes Mauritius, 0.07; New Caledonia, 0.85; and New Guinea (Australian Mandate), 9.30. The Adelie Land, Antarctic Regions, fall has been omitted from this table because of lack of information concerning the land area involved.

TABLE 3

THE AREAL CONCENTRATION OF THE METEORITIC FALLS OF THE CONTINENTS AND OF THE WORLD[1]

		— A. —		— So. —		— Si. —		TOTAL — O —		— U —		— T —		
CONTINENT	$a/10^4$	n	c	n	c	n	c	n	c	n	c	n	c	d
AFRICA	1150	41	0.0357	2	0.00174	28	0.0243	40	0.0348	31	0.0270	71	0.0617	402
AUSTRALIA	297	25	0.0840	8	0.0269	54	0.181	5	0.0168	82	0.276	87	0.292	185
EURASIA	2074	455	0.219	18	0.00868	77	0.0371	452	0.219	98	0.0473	550	0.265	194
ASIA	1699	170	0.100	8	0.00471	32	0.0188	175	0.103	36	0.0212	210	0.124	284
EUROPE	375	285	0.760	10	0.0267	45	0.120	278	0.741	62	0.165	340	0.907	105
NORTH AMERICA[2]	956	261	0.273	23	0.0241	297	0.311	108	0.113	473	0.495	581	0.608	128
SOUTH AMERICA	681	26	0.0382	8	0.0117	45	0.0660	14	0.0205	65	0.0954	79	0.116	294
MISC.[3]	593	17	0.0287	1	0.00169	2	0.00338	15	0.0253	5	0.00844	20	0.0338	544
THE WORLD	5751	825	0.143	60	0.0104	503	0.0875	634	0.110	754	0.131	1388[4]	0.241	204

NOTES TO TABLE 3

[1] See Note to Table 1, *ante*.

[2] Includes Central America, 21.59 (3); Cuba; Greenland, 83.97; and Jamaica. See the bracketed statement in *Studies: 1*, Table 3, Note 3.

[3] Includes the Antarctic Regions, Hawaiian Islands, Java (8), Mauritius, New Caledonia, New Guinea, New Zealand (4), and Philippine Islands (3).

[4] The difference of 4 falls between the 1392 of *Studies: 1* and the 1388 of the present investigation is due to the elimination of the following duplicates, discovered since the completion of the first paper:

(1) Chile: Corrizatillo, Copiapo, Atacama (G. T. Prior: *Catalogue of Meteorites*, p. 44, 1923) and Galleguillos, Copiapo, Atacama (*ibid.*, p. 63).

(2) China: Liweipantsûn, Eastern Kiangsi (A. D. Nininger: *C.S.R.M.*, **2**, No. 3, 230; *P.A.*, **48**, 558, 1940) and Yûkan, Eastern Kiangsi (A. L. Coulson: *Mem. Geol. Surv. India*, **75**, 230, 1940).

(3) Korea (Chosen): Gyokukei, Keisyô-hokudô (A. D. Nininger: *loc. cit.* (2), *ante*) and Zindoo, Keishohokudo (P. M. Millman: *Jour. Roy. Astr. Soc. Canada*, **32**, 202, 1938).

(4) Wales: Pontlyfni, Carnarvonshire (A. L. Coulson: *loc. cit.* (2), *ante*, p. 178) and Pontlyfni, England (P. M. Millman: *loc. cit.* (3), *ante*, p. 204). This fall belongs evidently to Carnarvonshire, Wales; there is no "Pontlyfni, England," fall.

(6) The 7 countries having the highest concentration of all 3 varieties of falls (both *O* and *U*) combined are Czechoslovakia (4.24, 48),[3] Switzerland (3.76, 52), France (2.63, 62), Belgium (2.55, 63), Holland (2.38, 65), Lithuania (2.33, 66), and Japan (2.30, 66). *Cf.* the U.S. with 1.68, 77.

Turning lastly to Table 3, we find that—

(1) (*a*) The continent having the highest concentration of A. falls is Europe alone (0.760; Eurasia with 0.219 is outranked, however, by North America with 0.273). (*b*) The continent having the lowest concentration of A. falls is Africa (0.0357).

(2) (*a*) The continent having the highest concentration of So. falls is Australia (0.0269; *cf.* Europe alone with 0.0267). (*b*) The continent having the lowest concentration of So. falls is Africa (0.00174!).

(3) (*a*) The continent having the highest concentration of Si. falls is North America (0.311; *cf.* Australia with 0.181). (*b*) The continent having the lowest concentration of Si. falls is Asia alone (0.0188; Eurasia with 0.0371 ranks higher, however, than Africa with 0.0243).

(4) (*a*) The continent having the highest concentration of *O* falls is Europe alone (0.741) or Eurasia (0.219). (*b*) The continent having the lowest concentration of *O* falls is Australia (0.0168).

(5) (*a*) The continent having the highest concentration of *U* falls is North America (0.495). (*b*) The continent having the lowest concentration of *U* falls is Asia alone (0.0212; Eurasia with 0.0473 ranks higher, however, than Africa with 0.0270).

(6) (*a*) The continent having the highest concentration of all 3 kinds of falls (both *O* and *U*) combined is Europe alone (0.907, 105; Eurasia, for which the figures are 0.265 and 194, is outranked, however, by North America [0.608, 128]). (*b*) The continent having the lowest concentration of falls is Africa (0.0617, 402). *Cf.* the preceding figures with the data for the entire world, for which, *e.g.*, the final $c = 0.241$ and $d = 204$.

It is illuminating to compare the conclusions reached in this paper with those contained in *Studies*: 1. In many cases the results herein arrived at are in striking contrast to, though they are of course quite in harmony with, those set forth in the earlier paper. We detect in the present analysis, even more clearly than in the preceding, *density of population* as a reason for the *concentration* of known meteoritic falls and we recognize an additional factor in the recovery of meteorites from a given area *A* of the Earth's surface,[4] namely (16) that—

A has been populated, at least by civilized man, during a longer period of time.

NOTES

[1] Which appeared in *C.S.R.M., P. A.*, **49**, 151-9, March, 1941, and which, for brevity, will henceforth be referred to as *Studies: 1*.

[2] This and like numbers are the appropriate values of *c*.

[3] This and similar numbers are the values of *d* in miles, according to the final column of the table.

[4] Kansas has the highest concentration of falls, not only of the States of the Union but also of the countries of the world, while North Carolina runs it a close second.

[5] Although these figures constitute a world's record for a *country*, they are outclassed by those for 4 *States* (namely, Kansas, North Carolina, Kentucky, and Tennessee); see Table 1 and the discussion following it, *ante*.

[6] *Cf.* the 15 points enumerated at the close of *Studies: 1.*

A Numerical Designation for Meteoritic Falls

By Frederick C. Leonard

In an earlier note (*C.S.R.M.*, **2**, No. 1, 64; *P.A.*, **46**, 581-2, 1938; see also *C.S.R.M.*, **2**, No. 2, 155-6; *P.A.*, **47**, 566-7, 1939), it was urged that the longitude (L) and the latitude (ϕ) of every meteoritic fall be recorded. It is now proposed that a numerical designation, devised to give *per se* the longitude and the latitude of the fall, be employed in conjunction with (*not* as a substitute for) the geographical designation.

The idea has been suggested by the system in use for many years at the Harvard College Observatory for designating variable stars. That consists in giving to each variable (in addition to its technical name) a 6-digit number, the first 4 digits of which express the star's right ascension (α), to the nearest minute of time, and the last 2, its declination (δ, both quantities for the year 1900), to the nearest degree; *e.g.*, 213843 represents SS Cygni (1900 $\alpha = 21^h\,38^m$, $\delta = +43°$) and 0214*03*, *o* (Mira) Ceti (1900 $\alpha = 2^h\,14^m$, $\delta = -3°$). If the declination is south (negative), the final 2 digits of the number are *italicized* (or *underscored*).

It is here proposed that a meteoric fall be similarly designated, by means of a 7-digit number, the first 4 digits of which shall give the longitude (L) and the last 3, the latitude (ϕ) of the place of the fall, each coördinate to the nearest *tenth of a degree*. If the longitude is east (negative), the first 4 digits should be italicized (or underlined), while if the latitude is south (negative), the final 3 digits should be italicized (or underscored): *e.g.*, for Canyon Diablo, Arizona (W. 111° 7′, N. 35° 10′), the appropriate number is 1111352; for Imilac, Desert of Atacama, Chile (W. 60° 14′, S. 23° 49′), it is 0602*38*; for Dhurmsala, Kangra Dist., Punjab, India (E. 76° 28′, N. 32° 14′), it is *0765*322; and for Hoba West, Grootfontein, Southwest Africa (E. 17° 55′, S. 19° 35′), it is *0179*196.

If 2 or more distinct falls with identical coördinates (to the nearest tenth of a degree) are known, these falls should all bear the same 7-digit number, to which in each case should be affixed a capital letter assigned alphabetically in the chronological order of the discovery of the fall; *e.g.*, Canyon Diablo, Arizona, No. 1 should be designated as no. 1111352A; Canyon Diablo, Arizona, No. 2 as no. 1111352B; *etc.*

It is emphasized that—as in the case of variable stars—the proposed numerical designation of meteoritic falls is intended only to supplement (not to replace) the usual (for falls, the geographical) designation. The advantages of both the numerical and the geographical designation are so apparent as to require no discussion.

In order to avoid in future any inaccuracy or ambiguity in recording the *time* of an *observed* fall, it is again recommended that the *Standard Time* (*e.g.*, the P.S.T.) in use at the place of the fall be registered, and further that this time be marked as either A.M. or P.M.; attention to the latter detail is obviously essential if civil time is employed, as is commonly the case. It is highly desirable to give also the corresponding *Greenwich* Civil Time (G.C.T. or U.T.). In any event, unless a definite statement to the contrary is made, it is reasonable (and generally safe) to assume that the time listed for an observed fall is the A.M. or

P.M. *Standard Time* (*not* the "daylight-saving"—"summer"—or some other kind of time) in use at the particular place.

Contraterrene (?) Meteorites

By H. H. NININGER

ABSTRACT

This is a reply to two articles published in the February, 1941, instalment of the *C.S.R.M.*, in which *contraterrene meteorites* were postulated to explain certain meteoritic phenomena. The present paper shows that all of the phenomena referred to can be explained on the basis of demonstrated facts without assuming the existence of any such purely hypothetical material.

In *C.S.R.M., P.A.*, **49**, 99-104, Feb., 1941, we find two attempts to explain puzzling meteoritic phenomena on the basis of the arrival on the Earth of so-called *contraterrene meteorites. If contraterrene matter* were known to exist and *if* such matter were known to exist moreover in the form of *meteorites*, it might indeed afford a very handy solution to many baffling problems! However, before there develops an epidemic of referring all "baffling problems" to this as-yet-undemonstrated kind of matter, the writer as a practical field man would like to say that in none of the cases discussed in the February, 1941, issue referred to previously, does he see the slightest excuse for resorting to the postulation of theoretically prescribed behavior for hypothetical matter in the form of a meteorite such as has never been known to exist.

As to the failure, thus far, on the part of the Russian meteorite expeditions, to recover any masses of meteoritic material from the region of the famous Podkamennaya Tunguska, Siberia, fall of 1908; and likewise the failure, so far, on the part of all field expeditions, to find meteorites in connection with the "Carolina Bays," it may be stated that these failures are by no means proof that such materials do not exist. The Siberian fall occurred in a region where field work is indeed very difficult. Had the great Arizona Meteorite Crater been produced in a similar region, I seriously doubt whether a single meteorite would have been found to prove its true nature. In spite of the barren and dry character of the terrain around the Arizona Crater and its unusual resistance to penetration, together with the shifting of its scanty soil by the wind, the great majority of all expeditions thither in search of meteorites have been unsuccessful. The American Meteorite Laboratory has proved the existence of scores, hundreds, and even thousands, of meteorites in areas no larger than 6 square miles where several earlier expeditions had reported "no meteorites." Unless the terrain to be investigated is suitable for the use of detectors, magnetic devices, or implements of cultivation, the ordinary sprinkling of meteorite fragments around a crater is indeed difficult to discover. The Carolina Bays, if meteoritic, are so ancient as to render the discovery of meteorites there very difficult, if not impossible.

With reference to the failure to find any evidence of craters associated with certain deposits of tektites, it may be said that the postulated relationship between these interesting lumps of glass and meteorite impacts on the Earth has rested on but slender evidence, as even the promulgator of the idea has admitted in some of his writings. The idea has never enjoyed wide acceptance.

For assigning such an ultra-hypothetical explanation to the "Phantom Bertha" story quoted from *The New York Times* of September 15, 1940, there is not the

slightest justification. The story quoted is entirely consistent with an ordinary daylight meteorite fall, such as hundreds that have been related either in the literature on meteorites or to the writer in conversation with witnesses of such events. The screeching sound was that produced by the non-luminous phase of the meteorite's passage through the air at a velocity approximating that of sound. At almost the same instant there arrived the detonation from the stratospheric explosion of the body. The "tower of water" was simply the result of the meteorite's plunge into the sea.

We should never be afraid to look for new facts or new explanations, but, so long as well-established facts are sufficient to explain a given set of phenomena, we are surely courting a return to the days of "spirits and mystery" when we shrink from painstaking (or even back-breaking) investigation and seek refuge in untried hypotheses, especially when those hypotheses rest entirely on assumptions!

Twelfth Meteoritic Fall Known to Have Damaged a Building

An omission from my list of 11 meteoritic falls certainly known to have damaged buildings, quoted by Mr. Ben Hur Wilson in his paper on "A Method of Estimating the Absolute Number of Meteorites," *P.A.*, **48**, 367, 1940, has been called to my attention by Professor Lincoln La Paz. The aërolitic fall at Strathmore, Perthshire, Scotland, on 1917 December 3, 1:15 P.M., which penetrated the roof of a house, should be added to the 11 falls of my list, *loc. cit.*

H. W. NICHOLS

Field Museum of Natural History, Chicago, Illinois

Fellows Elected and New Committee Appointed

As of date February 24, 1941, the Council has elected the following members to fellowship in the Society:

Dr. S. L. Boothroyd, Professor of Astronomy and Geodesy, Cornell University, Ithaca, New York;

Mr. Walter W. Bradley, State Mineralogist, State Division of Mines, Ferry Bldg., San Francisco, California; and

Dr. Carl O. Lampland, Astronomer, Lowell Observatory, Flagstaff, Arizona.

Under date of January 2, 1941, the Executive Committee of the Council has appointed the following *Committee on the Legal Ownership of Meteorites*: Messrs. J. H. Pruett (Chairman), W. W. Bradley, E. G. Linsley, H. A. Meyerhoff, H. W. Nichols, S. H. Perry, N. Schwartz, and E. S. C. Smith.

ROBERT W. WEBB, *Secretary*

Nominees for the Council for the 1941-45 Term

In accordance with Art. 3, Sect. 3 of the Constitution of the Society, the Council has nominated the following fellows for election to the Council for the 1941-45 term. The election will occur at the Eighth Meeting of the Society, which, as announced in the March issue, will be held at Flagstaff, Arizona, on June 23, 24, and 25, 1941. The new Council will take office on the adjournment of that meeting.

President: Dr. Lincoln La Paz, Ohio State University, Columbus

Vice-Presidents: Dr. F. R. Moulton, Smithsonian Institution Bldg., Washington, D. C.

Dr. Charles P. Olivier, Flower Observatory, University of Pennsylvania, Upper Darby
Dr. L. J. Spencer, 111 Albert Bridge Rd., London, S.W. 11, *England*
Secretary: Dr. C. H. Cleminshaw, Griffith Observatory and University of Southern California, Los Angeles
Treasurer: Major L. F. Brady, Mesa Ranch School, Mesa, and Museum of Northern Arizona, Flagstaff
Editor: Dr. Frederick C. Leonard, University of California, Los Angeles
Councilors: Professor Earle G. Linsley, Chabot Observatory and Mills College, Oakland, California
Dr. Howard A. Meyerhoff, Smith College, Northampton, Massachusetts
Mr. Oscar E. Monnig, Texas Observers, 312 W. Leuda St., Fort Worth, Texas
Dr. F. A. Paneth, University of Durham, Durham, *England*
Mr. Stuart H. Perry, *Adrian Telegram*, Adrian, Michigan
Professor J. Hugh Pruett, University of Oregon, Eugene
Dr. Fred L. Whipple, Harvard College Observatory, Cambridge, Massachusetts

The retiring President, Dr. H. H. Nininger, Colorado Museum of Natural History and American Meteorite Laboratory, Denver, will be *ex officio* a Councilor during the 1941-45 term.

ROBERT W. WEBB, *Secretary*

Notice Concerning Reprints of Papers

Reprints of papers published in the *C.S.R.M.* can be supplied to authors, *at cost price to* POPULAR ASTRONOMY, *only if ordered at the time manuscripts are submitted.* Requests for reprints, with or without titled covers, should be made, then, *when manuscripts are forwarded to the Editor of the Society.*

Comet Notes

By G. VAN BIESBROECK

No new comets have been added to the list of three that were announced in January but observations have been continued on all of these.

COMET 1941 *a* (FRIEND): This object has behaved very much as was predicted from the preliminary computations. It reached maximum brightness about February 15 when I estimated the total magnitude as $8^{M}.5$ by extra-focal comparison with neighboring stars. It appeared then as a round coma of about 6′ in diameter. There was a tiny stellar nucleus of magnitude 11 surrounded by a pear-shaped diffuse condensation. Figure 1 gives an idea of this appearance. It was enlarged from a plate exposed for 20 minutes at the 24-inch reflector and guided on the rapidly moving object as indicated by the long star trails.

After that date the brightness dropped rapidly while the comet moved swiftly southward. There has been some difficulty in representing the data of observation, probably owing to the fact that the orbit differs appreciably from a parabola. Further observations will settle that question before long. The present full moon has put a stop to the observations on this very diffuse object, which will soon be very faint and too far south for observation in this latitude.

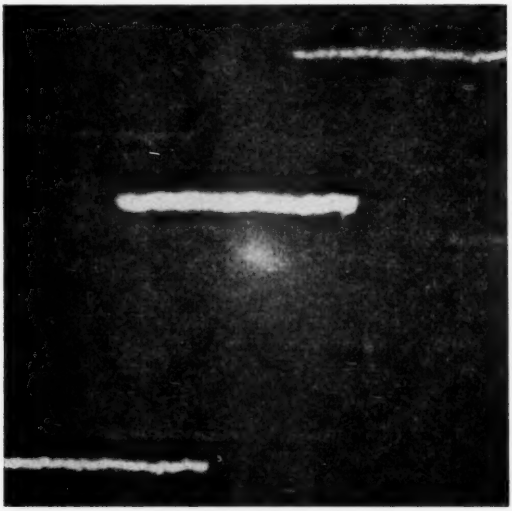


FIGURE 1
COMET 1941 *a* (FRIEND)
1941 FEBRUARY 15

COMET 1941 *b* (PERIODIC ENCKE): Further observations have been secured here up to March 1 on this very poorly situated comet. It could be seen only at low altitude shortly after sunset, remaining a faint and diffuse object whose magnitude I estimated as 13 on March 1. The coma seemed to show a projection in the direction of the sun suggesting a beginning of physical activity, now that the comet comes within the earth's orbit.

The decreasing angular separation from the sun will make further observations impossible. In a couple of months the comet should be fairly bright for southern observers.

COMET 1941 *c* (PARASKEVOPOULOS and others): Many observations have been secured on this comet last month when it could be seen easily with the naked eye although it faded rapidly towards the end of February. Figure 2 shows the appearance of this bright object on February 16, when I secured here a 13-minute exposure with the 24-inch reflector. The head is, of course, considerably overexposed and the bright stellar nucleus is lost in the photographic process. The tail starts out in paraboloid shape with an apparent hollow core but, some 40′ from the nucleus, it merges into a bundle of filamentary streamers some of which have on the original negative a distinctly wavy appearance. Unfortunately, these faint extensions are very largely lost in the reproduction.

The ephemeris is continued here from A. D. Maxwell's elements (p. 168):

1941		α	δ
March	31	$2^h\,10^m$	$+11°.8$
April	4	11	12.3
	8	13	12.7
April	12	2 14	+13.1

It shows that on the last date given the comet will be within 15° of the sun and therefore hardly observable any more. It will probably be seen again in a couple of months in the morning, however, very much reduced in brightness.

FIGURE 2

COMET 1941 *c* (PARASKEVOPOULOS)
1941 FEBRUARY 16

At this time the search for the expected return of PERIODIC COMET 1930 VI (SCHWASSMANN-WACHMANN) should be made. From the observations at the first return a period of 5½ years was deduced which should have brought the object back in 1935-1936. The geometric circumstances of observation were however so unfavorable at that time that the comet could not be observed. This year the comet is better placed. F. R. Cripps has applied the perturbations by Jupiter, Saturn, and the Earth for the two revolutions elapsed since 1930 and gives the following ephemeris (*Handbook of the British Astronomical Association* 1941):

1941	α			δ		—Distance from— Earth	Sun	For perihelion one day later	
	h	m	s	°	′			s	′
Mar. 27	20	13	10	—15	32	0.998	1.057	—211	+16.0
Apr. 4	20	55	33	16	0	1.001	1.032	—203	+11.0
12	21	36	47	15	59	1.018	1.017	—187	+ 6.6
20	22	16	5	15	32	1.046	1.015	—166	+ 2.5
28	22	52	42	14	43	1.080	1.025	—145	— 0.9
May 6	23	26	26	—13	40	1.112	1.047	—124	— 3.7

This prediction assumes perihelion on the date of April 17.409, 1941. The last columns indicate the variation in position to be expected if the date falls one day later.

This comet will be much fainter than in 1930, when it reached magnitude 7 at the time when the distance from the earth was less than one-tenth of an astronomical unit. The corresponding expected magnitude would be around 12 for the time covered by the ephemeris and would be almost constant during that interval. The comet should be searched for in the morning sky.

Williams Bay, Wisconsin, March 11, 1941

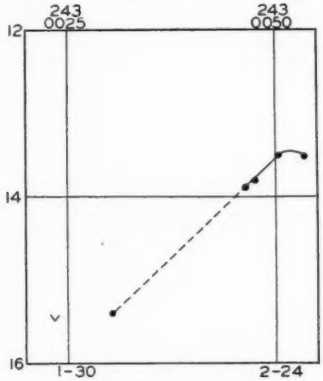
VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

Another Supernova: Supernovae, those intrinsically bright novae which make their sudden appearance in the distant galaxies, continue to claim the attention of the astronomical world. Another has recently been found by Miss Rebecca Jones at Harvard Observatory in the wide, open-armed, (Class Sc) system NGC 4559, located in R.A. $12^h\,33^m.0$ and Dec. $+28°\,17'$.

Prior to discovery, the supernova was at least fainter than the eighteenth magnitude. On February 5, 1941, when the first plate was secured on which the nova was seen, it was of photographic magnitude 15.4. On February 20, two weeks later, it had risen to magnitude 13.9, and for the next week it appeared to be steadily increasing in light, to magnitude 13.5 on February 27. The plot of the light curve, so far observed, is shown in the accompanying figure.



PHOTOGRAPHIC OBSERVATIONS OF SUPERNOVA IN N.G.C. 4559

What happened between February 5 and 20 remains as yet unknown, and accordingly it will be highly important to learn if the star was photographed with any other large telescope besides those at Harvard. NGC 4559 has a total

photographic magnitude of 10.7; it is one of the brighter external galaxies, so that the nova can not be called an exceedingly bright supernova, unless we find that it had brightened considerably around the middle of February.

Classification of Variable Stars: For the past sixty years there have been various attempts at the classification of variable stars. E. C. Pickering, in 1881, suggested a system which, for its day, appeared to represent rather satisfactorily the types of variables then known, and which for many years was made the basis of other classifications. He proposed five general classes, or types, as follows:

I Novae
II Long-period variables
III Irregular variables
IV Short-period variables
V Algol variables

In class II there were later included, as sub-classes, the U Geminorum and R Coronae Borealis-type stars, on the assumption that their departure from normal brightness, whether from minimum or maximum, occurred at relatively long intervals of time. III (Irregulars) was made a sort of dumping ground for those stars which could not well be relegated to other groups.

As more data were accumulated on the variables in general, and on those which appeared to present anomalies in their regular variations, other classifications were presented. Ludendorff, in 1928, offered what seemed to be a very all-inclusive classification, as follows:

I Novae
II Nova-like
III R Coronae Borealis-type
IV U Geminorum-type
V Mira Ceti-type
VI μ Cephei-type
VII RV Tauri-type
VIII Long-period Cepheids
IX Short-period Cepheids
X Eclipsing binaries.

More recently, in 1938, Drs. C. P. and S. Gaposchkin, in their book, "Variable Stars," proposed a classification based on four main, physical criteria:

A. Geometrical Variables: including all those stars which we observe as variable mainly because of their position with respect to our line of sight. This group includes all eclipsing binaries, of whatever type; the ellipsoidal stars; and the stars which are obscured by a nebula, but not an actual part of the nebula.

B. The Great Sequence of Intrinsic Variables: all intrinsic variables which present a definite periodicity; those whose light curves are never steeper in decline than rise; those whose light curves repeat themselves more or less uniformly; those whose spectra, radial velocities, and colors vary continuously throughout their period of light variation; and lastly, the stars which follow a definite period-luminosity and period-spectrum relation. Included in this main group are the Long-period, Mira stars; Cepheids and Cluster-type variables, the Semi-regular variables; and the Irregular, Red variables.

C. The Cataclysmic Stars: comprising the Novae; stars of the SS Cygni or U Geminorum-type; and those of the R Coronae Borealis-type. These stars have been termed cataclysmic, which as the name implies, refers to the suddenness of their behavior, either in becoming exceedingly bright, as for Novae, or moderately bright at frequent intervals, such as SS Cygni; and the R Coronae Borealis stars, which, without apparent warning, suddenly fade away to a marked degree of faintness.

D. Extrinsic, or Nebular Variables: those variables which lie in between the geometric and intrinsic variables, and are usually involved in, or associated with, nebulae. This class would include the Orion group of irregular variables and

many other associated with nebulosities.

In the course of a recent compilation and discussion of data on variable stars, Campbell and Jacchia find that a rather natural grouping of the variables suggests itself as follows:

Classes	Examples
I Novae	
Ordinary	DQ Herculis, 1934
Super	S Andromedae
Recurring	RS Ophiuchi
II Nova-Like	
U Geminorum-type	SS Cygni
Z Camelopardalis-type	RX Andromedae
III Long-Period	
Me and Se Stars	o Ceti and χ Cygni
Ne and Re Stars	R Leporis and S Camelopardalis
IV Cepheids	
β Canis Majoris	β Cephei
Cluster	RR Lyrae
Classical	δ Cephei
Semi-regular	RV Tauri
V Eclipsing	
Algols	β Persei
W Ursae Majoris-type	RR Centauri
Ellipsoidal	π5 Orionis
VI Peculiar Red Giants	
Semi-Regular	V Ursae Minoris
Irregular	μ Cephei
VII Erratic	
R Coronae Borealis-type	RY Sagittarii
Nebular Stars	T Orionis
Rapidly Irregular	RR Tauri
Be Stars	γ Cassiopeiae.

New Light on Five Red Variables: A small group of variable stars, recently studied by the Milton Bureau, offers some interesting contrasts in behavior in relation to spectral class. The stars in question are all in the constellation Camelopardalis, and bear the letters V, X, S, T, and ST. For all of them the photographic observations have produced a fairly continuous record for the past fifty years, and the first four named have been kept under unremitting watch by the A.A.V.S.O. Comparison of the visual and photographic light curves shows some interesting contrasts in color index.

The bluest of the stars is X Camelopardalis, with an average color index rather over a magnitude. This star, which has a spectrum of Class M3e at maximum, is considerably bluer at minimum and redder at maximum than its average color.

Next in color is the star V Camelopardalis, which has a spectrum of Class M7e; its color index (which, because of faintness, can be studied only at maximum) is about 1.7 magnitudes.

T Camelopardalis has a spectrum of Class Se. The photographic and visual curves are interesting in showing similar variations of shape. At maximum, T Camelopardalis has a color index of a magnitude and a half, and it becomes much redder as the light diminishes. The actual minimum is not covered by the photographic observations, but when the star is about two magnitudes above minimum, the color index is about three magnitudes. These color changes are reproduced in miniature through the hump on the rising branch of the light curve.

S Camelopardalis has a spectrum of Class Re. Its color index amounts to three

magnitudes, soon after minimum phase, while at maximum it is about two magnitudes. The irregularities of the visual light curve are not conspicuously shared by the photographic light curve as is the case for T Camelopardalis.

The light curve of ST Camelopardalis, a star of Class Nb, has hitherto been regarded as irregular. In point of fact it very closely resembles that of W Orionis, which is a star of similar spectrum. There is a short period or cycle of about 195 days, and a longer cycle in mean brightness of about 2100 days. Furthermore, the star has gradually brightened from an average photographic magnitude of about $11^{M}.4$ at J. D. 2415000 to an average of about $10^{M}.2$ at the present time Probably this fluctuation is part of a long cyclical change in mean brightness which must last for at least 30,000 days. To judge from the somewhat infrequent visual observations, the star has a color index, at its maximum, of over three magnitudes. The individual changes of color cannot be studied with the existing material; probably the visual range, as with W Orionis, is smaller than the photographic range, so that even larger color indices may be expected near minimum light.

Observers and Observations received during February, 1941:

Observer	Var.	Obs.	Observers	Var.	Obs.
Ball, A. R.	9	9	Kelly	14	20
Bappu	27	67	Knott	1	1
Blunck	15	16	Koutz	16	24
Bouton	37	45	Livingston	13	13
Brocchi	13	20	Lovinus	8	8
Chilton	5	5	Mason	26	36
Cilley	31	53	Maupomé	50	50
Cousins	20	50	Nadeau	5	10
Diedrich	7	7	Parker	16	16
Escalante	47	83	Parks	27	44
Fernald	76	150	Peltier	49	67
Ford	7	7	Prinslow	4	4
Forrester	2	2	Purdy	8	8
Franklin	11	13	Rosebrugh	15	38
Griffin	40	40	Saxon	13	13
Halbach	1	1	Schoenke	8	18
Harris	35	35	Sill	34	34
Hartmann	135	187	Smith, F. P.	4	4
Hiett	8	14	Stahr, Miss	4	4
Hildom	2	2	Topham	14	14
Holmes, Mrs.	4	4	Walton	7	8
Holt	124	234	Webb	22	22
Kearons, Mrs.	72	173			
			45	Totals	1673

March 14, 1941.

Notes from Amateurs

Yakima Amateur Astronomers

At the anniversary banquet and annual meeting held on December 10, the officers for 1940 were all re-elected for the year 1941. They are: Edward J. Newman, president; Orris Thompson, vice-president; Carol Smith, secretary; and William Hillman, treasurer. At this meeting an interesting program was given which included a short talk by Father Egan and the showing of two films on astronomy, which were very well received.

Yakima, Washington.

Cleveland Astronomical Society

Although the public was admitted by ticket, the new auditorium of the Warner and Swasey Observatory was filled to capacity on the evening of March 7, with persons who had come to hear Dr. Donald Menzel, Professor of Astrophysics, Harvard University. His subject, "The Mystery of the Sun," proved of utmost interest. He also showed a remarkable motion picture of the solar prominences and sun-spots and described the new Solar Observatory which is located 11,000 feet above sea level at Climax, Colorado. Dr. Menzel is director of this unique observatory which was designed to study the sun, particularly the phenomena which in the past were observable only at the time of total solar eclipses. Dr. Menzel founded the observatory and his work there is unique in America and will play an important part in long-range weather forcasts.

Two public nights, March 13 and 14, were announced by Dr. J. J. Nassau, professor of astronomy at Case School of Applied Science and director of the Warner and Swasey Observatory. At that time he will discuss the giant red stars which wander through the universe.

Our society is unique in that at some time or other we have had as guest speaker almost every prominent astronomer in the United States. The telescope makers group now has a total attendance of 60 and is under the direction of Mr. Russell. The society's library continues very popular, and donation of books to the library would be much appreciated whether from authors or private sources.

Euclid Beach Park, Cleveland, Ohio. DON H. JOHNSTON.

The September-October, 1940, Spot on Saturn

The observed surface of Saturn is so quiescent that it rarely presents markings or spots definite enough for use in determining rotation periods. The last spots to be seen and described at length were discovered in 1933 and discussed by L. J. Wilson[1] and B. M. Peek[2]. This was a white equatorial disturbance. In 1935 another white equatorial disturbance was observed by E. P. Martz, Jr., L. E. Armfield, and H. Wintersohle and described by Mr. Martz[3]. On July 1, 1936, M. E. M. Antoniadi, presumably using the 33-inch Meudon refractor, drew some "dusky condensations on the N. belt".[4] In 1938, Focas, using the 16-inch refractor of the National Observatory at Athens, drew some detail "at the edges of the belts and on the equatorial zone".[5]

In this report will be given an account of observations of a delicate, dark, elongated and rather indefinite spot or condensation-enlargement in the north edge of the south equatorial belt of Saturn, apparently first seen by the writer in Des Moines, Iowa, on September 14 and last seen by D. P. Barcroft of Madera, California, on October 30, a few days before opposition on November 3. Our observations are confirmed by additional ones which, though unrecorded, were made by F. R. Vaughn, Jr., also in Des Moines, Iowa, usually together with the writer. The dates and times of all the work have been reduced here to U.T. The apparent confirmation of the spot by three observers is of great importance in this case, for it was so delicate with the telescopes employed that the writer alone, for example, was never absolutely sure of its objective existence when it was under

[1] *P. A.*, **41**, 436, 1933
[2] *J. B. A. A.*, **44**, 220, 1934
[3] *Amateur Astronomy*, **2**, 46, 1936
[4] *J. B. A. A.*, **46**, 363, 1936
[5] *J. B. A. A.*, **48**, 382, 1938

view. Mr. Barcroft also is very conservative about the value of his single observation, nothing on his drawing showing the spot that it was only "suspected". It is not likely that European observers were able to observe and confirm this marking.

The method for observing spots on Saturn for rotation periods is the same as that used on Jupiter by amateurs, *i.e.*, obtaining the times of transit across the central merdian of the illuminated disk by visual estimation. On Jupiter such estimates are subject to chance errors of about five minutes, but on Saturn and especially for delicate marks we may expect larger errors. Table I summarizes the present work in this way. Column one gives the initials of the observer; column two, his telescope; column three, the magnification; column four, the seeing on a scale of 0 (poorest) to 10 (best); column five the date; column six, the U.T.; column seven, the number of rotations since the first transit; column eight, the difference between the uncorrected computed time of transit based on an arbitrarily adopted rotation period of 10h 18m and the observed time of transit; and column nine, notes on the transit.

TABLE I

Obs.	*Telescope*	*Mag.*	*Seeing*	*Date*	*Time*	*Rotations*	*C-O*	*Notes*
H.M.J.	8″ refl.	213X	6	Sept. 14	6^h 15^m	0	0^M	Central.
H.M.J.	8″ refl.	213X	6	Oct. 5	6 12	49	+47*b*	Central or just past.
F.R.V.	8″ refr.	240X	3-4	Oct. 15	3 50	72	+ 1*c*	Slightly past.
H.M.J.	8″ refr.	240X	3-4	Oct. 15	3 50			Central or slightly short.
H.M.J.	8″ refl.	213X	6-7	Oct. 21	3 30	86	+23*d*	Slightly short.
H.M.J.	8″ refl.	213X	6-7	Oct. 21	3 45			Central or slightly past.
D.P.B.	6″ refl.	96X 144X	4*a*	Oct. 30	5 23	107	—59*e*	Central or just past. *f*

Notes—*a* Adopted from estimate of 2 on a scale of 1-5.
b Adopted time of transit: 6^h 10^m.
c Adopted time of transit: 3^h 50^m.
d Adopted time of transit: 3^h 40^m.
e Adopted time of transit: 5^h 20^m.
f From drawing.

It will easily be seen that these observations can not be harmonized well in any way. But we must remember these two points in interpreting them: (1) The spot was elongated and indefinite; it is therefore possible that different parts of it impressed the eye on different occasions, or even that there was more than one condensation. (2) The spot may have had a variable rotation period; indeed, we may *expect* some such variation. If we accept Barcroft's observation as having any real meaning, condition (2) is practically forced on us. As an alternative we might reject this observation, but when taken with Barcroft's the other four transit times might give indication of a continuous *deceleration* of the rate of motion of the spot. Acknowledging this deceleration, we find that the spot was first observed with a rotation period less than the arbitrary reference period of 10h 18m, which through deceleration became equal to that period some five or six weeks later and at the end of the 46 days of observation possessed a rotation period greater than 10h 18m.

There are certain ordinarily necessary corrections to apply to any set of direct observations of a planetary marking for rotation period. These are: (1) Change

in phase, since we are observing marks relative only to the visible illuminated portion of the planet. (2) Change in light time. (3) Change in the direction of the planet from the Earth. For Saturn (1) is negligible, especially near opposition. From data in the *American Ephemeris* for 1940, it is computed that the change in light time for Saturn between September 14 and October 30 was three minutes. A rough computation gives approximately 3°.5 as the angle required in the present case for (3). Now with a rotation period of 10h 18m for a planet, 3°.5 in longitude equals six minutes. These results for (2) and (3) show that, like (1), they are negligible, being within the errors of observation (and here partially counteractive).

We can therefore compute directly the average rotation period for this spot from September 14 to October 30. The result gives 10 hours 19.3 minutes.

It remains to find the latitude of this spot, for on Saturn there seems to be an even greater variation in rotation period with latitude than on Jupiter. The spot has been placed in the dark "south equatorial belt", the band bordering the south edge of the white equatorial zone of Saturn in 1940, but this appellation is rather arbitrary. On 1941 February 9, $0^h\ 04^m$, a careful visual estimate by the writer placed the intersection of the south equatorial belt with the central meridian nearly midway between the north and south limbs or perceptibly north of the mid-point, say $.02R$, where R is the polar radius. Then $.02 = \sin |\beta - B|$, approximately, where β is the latitude of the belt, negative for the southern hemisphere, and B is the planetocentric declination of the Earth, also negative toward the south. With $B = -19°$ on February 9, we find $\beta = -18°$, approximately.

HUGH M. JOHNSON.

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February 12, 1941.

Communications and Comments

Under this heading we shall publish from time to time such material as does not properly fall under any of the established headings of this journal. Here, too, may be found, when occasion arises, articles which the editor may not be willing to give sanction to but which, nevertheless, may be provocative of thought along new lines.

Sky Illumination Observed

A sky phenomenon, which attracted considerable attention, was observed here and at other places in the vicinity of Raleigh on the evening of March 1. It was a striking light-effect visible in the western sky from 7:00 to 9:00 P.M. As I observed it about 8:00 o'clock its position and form were almost identical with those of the Zodiacal Light. Its appearance as to brightness and color was similar to that of a solar corona at the time of an eclipse. It was brightest just above the horizon. It was triangular shaped, as the Zodiacal Light, and the new moon was almost in the center of the apex towards the top. Numbers of our students here saw it and they report that it reached its maximum brightness about 7:30. Some of them reported coloring effects associated with it, and some observed a luminous patch in the East. When I observed it there were no colors, and I observed no light effects anywhere except in the West along the ecliptic. One of our faculty members on a visit to a town 50 miles south of Wake Forest observed the same phenomenon. Many people in Raleigh observed it and called us by telephone concerning it.

The fact that the phenomenon arrested the attention of so many casual observers is proof of the fact it was something unusual.

The light had the appearance of a glow discharge. I am inclined to believe that the effect was the result of ionization in region of the atmosphere west of this locality. I do not believe that there was any connection between it and the Zodiacal Light except form and position which was probably accidental. It is true that the ionosphere was misbehaving on March first, for on that day radio communication was greatly interfered with by magnetic storms. The most puzzling problem seems to be location. One would expect to see such a display in the northern sky, call it an aurora display, and let the matter rest.

My primary object in writing this letter is to inquire if you have had any reports of this from any other part of the country. I would appreciate hearing from you.

W. E. SPEAS.

Wake Forest, N. C., March 11, 1941.

General Notes

Dr. Y. C. Chang, who took his Ph.D. degree at the University of Chicago for work done at the the Yerkes Observatory in 1929, has been appointed director of the Institute of Astronomy, Academia Sinica, Kunming (Yunnan), China, upon the resignation of Dr. C. S. Yu. Professor Chang writes: "The difficulty of the task is enhanced by wartime conditions and the loss of instruments during the removal from Nanking to the present location." He independently discovered the Paraskevopoulos comet on February 2. He would welcome shipment of astronomical literature which is seriously lacking.

The Rittenhouse Astronomical Society, of Philadelphia, held its monthly meeting on Wednesday, March 5. At this meeting L. Don Leet, Ph.D., in charge of the Harvard seismograph station, gave a lecture on "Earthquakes".

The Royal Astronomical Society of England by action of its Council on November 8, 1940, has decided that it was inexpedient to award the Gold Medal this year.

Symposium on Astronomical Spectra

Next September the University of Chicago will celebrate its fiftieth anniversary. In this connection, the department of astronomy will arrange a symposium at the Yerkes Observatory on the subject of "Astronomical Spectra." A number of distinguished astronomers from other institutions will take part in this symposium, including Professor H. N. Russell and Dr. R. Wildt of Princeton, Professor D. H. Menzel of Harvard, Dr. M. Schwarzschild of Columbia, and Dr. R. C. Williams of Michigan.

The symposium will follow immediately after the meeting of the American Astronomical Society which will take place at the Yerkes Observatory between September 7 and 10.

The present members of the astronomy department hope that many former graduate students and alumni will come to Williams Bay for the meeting and the symposium. We shall try to arrange for an informal reunion of old Yerkes and

Chicago graduates and we extend to you a cordial invitation to join us. Accommodations, either for the entire week, September 7 to 13, or for a shorter interval, will be available at George Williams College Camp (formerly Y.M.C.A. College Camp) at about $2.25 per person a day, including meals.

OTTO STRUVE.

Yerkes Observatory, Williams Bay, Wisconsin.

The Determination of Definitive Comet Orbits

A summary of the present status of comet-orbit determinations was recently received from Dr. A. Kopff, director of the *Astronomisches Rechen-Institut*, in Berlin-Dahlem, Germany, with the request that, perhaps, we might supplement it from information not now available to him. We are glad to publish the complete summary for use by those workers who may not now have access to the *Astronomische Nachrichten*, and to add two items furnished us by Dr. G. Van Biesbroeck of the Yerkes Observatory.

Dr. Kopff says that various questions make it desirable to ascertain for which of the new non-periodic comets, as well as of the periodic ones which have been observed at only one appearance, definitive orbit studies are in progress. He says that to his knowledge definitive orbit determinations have been undertaken for the following comets by the persons indicated:

1919V	(Metcalf)	J. Witkowski
1924IV	(Wolf) [1925I]	S. Kanda
1929II	(Forbes)	Makarow
1930V	(Forbes)	E. Senftl
1930VI	(Schwassmann-Wachmann)	W. Parfenow
1932I	(Houghton-Ensor)	A. Przybylski and Frl. Kostyczyn
1932VII	(Newman)	Astron. Institut Leningrad
1936III	(Kaho-Kozik-Lis)	Astafov
1936IV	(Jackson-Neujmin)	L. E. Cunningham
1939*a*	(Kozik-Peltier)	A. Przybylski
1939*b*	(Väisälä)	L. Oterma
1939*d*	(Jurlof-Achmarof-Hassel)	M. Bielicki
1939*h*	(Rigollet)	T. Watanabe

For the following comets, no work is now being done, as far as he knows:

1911IV	(Beljawsky)	1923I	(Skjellerup)	1930IV	(Beyer)
1912III	(Borelly)	1924II	(Finsler)	1931IV	(Ryves)
1913I	(Lowe)	1925III	(Reid) [1925IV]	1931V	(Carrasco)
1914I	(Zlatinsky)	1925VI	(Shajn-Comas S.) [1925VII]	1932V	(Peltier-Whipple)
1914II	(Kritzinger)			1933I	(Peltier)
1914IV	(Campebll)	1926I	((Blathwayt)	1934II	(Jackson)
1915IV	(Mellish)	1926III	(Ensor)	1936I	(Van Biesbroeck)
1917II	(Schaumasse)	1926VII	(Reid)	1936V	(Hubble)
1918II	(Reid)	1927II	(Blathwayt)	1937II	(Wilk)
1920I	(Skjellerup)	1927IX	(Skjellerup-M.)	1937IV	(Whipple)
1920III	(Skjellerup)	1929III	(Neujmin)	1937V	(Finsler)
1921V	(Reid)	1930III	(Wilk)		

We add the following information: The orbit of Comet 1908 III (Morehouse) is at present under investigation by Dr. Van Biesbroeck. The orbit of Comet 1936 I (Van Biesbroeck) was completely studied by Dr. Van Biesbroeck, and the results were reported in *Publications of the Yerkes Observatory*, Vol. 8, Pt. IV.

Federal Government Recruits Meteorologists by Civil Service Examinations

A civil service examination to secure meteorologists for the Federal Government has been announced by the United States Civil Service Commission.

The positions pay from $2,600 to $5,600 a year, less the usual retirement deduction. Separate employment lists will be set up in such specialized branches of meteorology as climatology, dynamic meteorology, and radiometeorography.

The duties of these positions include planning, supervising, or conducting investigations or research work in the special branch of meteorology in which appointment is made. Applicants are especially desired who have had experience in meteorological research or in practical work in forecasting such as might be obtained with airlines.

Completion of a 4-year college course with major study in meteorology, physics, engineering, astronomy, geology, mathematics, or any other closely related subject is required. In addition, applicants must have had responsible professional experience in meteorology. Under certain conditions, both college teaching and graduate study in meteorology may be used to fill part of the experience requirement.

Although applications will be rated as received at the Commission's Washington office until December 31, 1941, qualified persons are urged to apply at once. Further information and application forms may be obtained at any first- or second-class post office, or from the Civil Service Commission, Washington, D. C.

Report on Astrology

The Scientific Monthly for March, 1941, contains a paper on the above topic. This report is made by a committee of the Boston and Cambridge Branch of the American Association of Scientific Workers and is signed by Bart J. Bok and Margaret W. Mayall.

The report calls attention to the lack of scientific foundation for the work done under the name of astrology. It is divided into six parts. (1) The horoscope and its interpretation; (2) Historical survey; (3) Press magazines and advertising; (4) Legal aspects; (5) The attitude of scientists; (6) Psychologists state their views on astrology.

Book Reviews

Literature and Science, Edited by Grant McColley. (Packard and Company, Chicago.)

This volume, issued in 1940, is described as an anthology from English and American Literature, 1600-1900. As is indicated by the title, the selections from the extensive literature were chosen because of their scientific bearing or content. The field and literature of each of the sciences, to say nothing of the whole of science, is so vast that a single volume could not contain even a suggestion of its ramifications. Such, however, is not the purpose of this book. The science included in it is incidental and serves merely as a subject about which to create a piece of literature. The technicalities are omitted and the comprehensive thoughts are given definite and in many instances elegant literary form.

The order of the selections is determined chiefly by the time they were written. Hence one finds "The Man in the Moon" by Francis Godwin and "The Butterfly" by Henry Power, or "The Principia" (Selections) by Sir Isaac Newton and "On the Flying Spider" by Jonathan Edwards rather close together. This arrangement makes it possible to trace the development of scientific thought

through these three centuries as it is expressed by those whose chief concern was not the advancement of science but the putting of the results of science into readable style. There are one hundred fifty titles included in the 511 pages, ranging from the writings of Francis Bacon and John Milton to those of Benjamin Franklin and Charles Darwin. Many of the selections are in the form of poetry in which in some cases, as is quite natural, the imagination outruns prosaic scientific fact.

The reviewer's experience repeatedly has been to take up the book for the purpose of securing some impressions concerning it, which might appropriately be included in a review, only to find himself presently entirely engrossed in the reading of one of the selections and utterly oblivious as to the purpose he had in mind at the outset. This experience, therefore, may be taken as an indication of his opinion of the book. More explicitly he would say that he believes that any one interested in the steady growth and progress of science will do well to have a copy of it at hand for casual reading. He will acquire an acquaintance with the elements of the several sciences and with the style of recognized literary personalities at the same time.

C.H.G.

Mr. Tompkins in Wonderland, by G. Gamow. 91 pp. (The Macmillan Company, New York. $2.00.)

The dedication of this book to Lewis Carroll and Niels Bohr is significant of its two-fold character. It is a delightful account of the unusual dream experiences of a little clerk in a big city bank, resulting from his attending a series of lectures on modern physics, but always the tale conforms to rigorous physical principles.

In his first dream the clerk finds himself in a toy universe where the velocity of light is ten million times smaller and the gravitational constant a million million times larger than usual. Furthermore, the universe is expanding and contracting with a period of about two hours. In his second dream the hero observes the action of strange billiard balls whose quantum constant is about unity. In his third dream he visits a city where the velocity of light is 10 miles per hour. In his fourth dream he travels with the physics lecturer to a region where the quantum constant is the same as in the second dream for the balls. The conditions obtaining in the fifth dream are the same as in the third. In his final or sixth dream he experiences a space quake in which various physical constants assume different values at different places.

The three popular lectures, which are supposed to have inspired the dreams, are appended. John Hookhan has drawn several clever and amusing illustrations for the book. The author is a professor of theoretical physics at George Washington University.

C.G.S.

Astronomical Series, Volume VI, Parts I, II, III, and IV, of the Publications of the University of Pennsylvania, have recently been issued in two octavo pamphlets. The first includes Parts I, II, and III, and is a discussion of visual and Photographic Photometry of the Eclipsing Variables, AD And, V343 Aql, and ER Ori, the result of studies by Philip K. Taylor and R. Stanley Alexander. The second, Part IV, has to do with the construction and use of an interferometer for the measurement of close double stars. This represents work done by Raymond H. Wilson, Jr., at the Flower Observatory. Copies of these pamphlets may be obtained from the University of Pennsylvania Press, 3622 Locust street, Philadelphia, for $1.50 each.